Compact Urban Form as a Tool for Improving Travel Behavior: A Case of Nashik City

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In
Urban Planning

by

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Under the guidance of

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I, **Divya Nair,** hereby declare that this Project Phase II titled **"Compact Urban Form as a Tool for Improving Travel Behavior – A Case of Nashik City"**is carried out by me in the Department of Architecture and Planning of Visvesvaraya National Institute of Technology, Nagpur. The work is original and has not been submitted earlier whole or in part for the award of any degree/diploma at this or any other Institution/University.

Divya Nair

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ABSTRACT

Compact urban form is a vital factor in promoting sustainable urban development. The physical structure and spatial configuration of cities directly influence how people travel, their mode choices, and the degree of reliance on different transportation systems. Various studies consistently demonstrates that compact cities characterized by higher densities, mixed land uses, and well-integrated public transport networks contribute to shorter travel distances, improved accessibility, and reduced environmental impact. By curbing urban sprawl and encouraging spatial proximity between residential, commercial, and recreational zones, compact development fosters walkability, reduces dependence on private vehicles, reduces the travel distance and improves accessibility. This study focuses on several medium-sized Indian cities such as Nashik, Vadodara, Pune, Thiruvananthapuram, Rajkot, Bhopal, and Coimbatore with Nashik as the primary case study. It explores how urban form indicators including density, land use mix, shape, porosity, compactness, and the availability of buildable land influence residents' travel behavior.

Through the application of spatial indicators and Geographic Information Systems (GIS), the research quantitatively examines the relationship between these variables and travel behavior metrics such as modal share, average trip length, transit accessibility, and proximity to services. Benchmarking these indicators across comparable cities reveals the importance of adopting spatial planning strategies that foster sustainable and self-reliant urban growth.

The analysis shows that Nashik's existing urban form contributes to longer travel distances and increased reliance on motorized transport, despite the potential for shorter, more efficient trips. The study concludes that advancing compact, dense, and well-connected urban development via Transit-Oriented Development (TOD), infill development, land readjustment, and mixed-use zoning can significantly reduce travel demand, promote sustainable mobility, and enhance climate resilience. This integrated planning approach is vital for Tier-2 cities seeking to manage rapid urbanization and transition toward inclusive, sustainable futures.

Keywords- Urban Form, Density, Transportation, Compactness.

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Chapter -1
INTRODUCTION

1.1 Background

India's urbanization has shown a steady but slower trajectory compared to global and regional trends. In 1950, only around 17% of India's population lived in urban areas, and by 2020, this rose to approximately 35%. Projections suggest that by 2050, about 50% of the population will reside in cities. In contrast, the global average of urbanization rose from around 30% in 1950 to 56% in 2020, and is expected to reach 68% by 2050(See Figure 1). More developed regions were already around 55% urbanized in 1950 and are projected to approach 90% by 2050(Hugo, 2019)(Zhang, 2016).

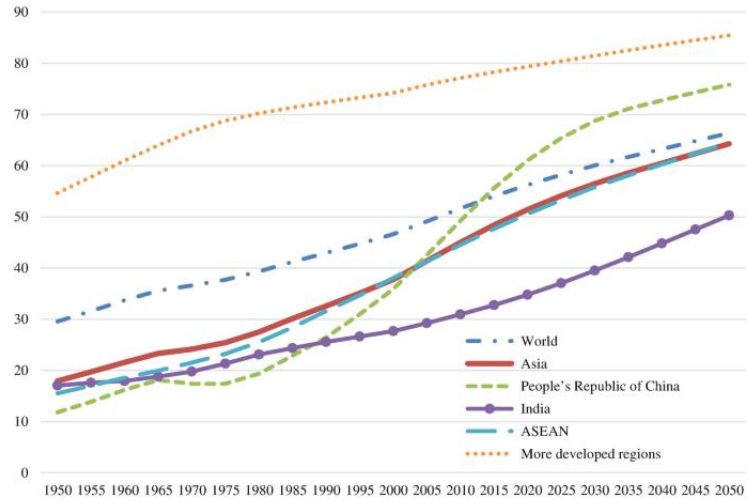


Figure 1- Urbanization of India v/s World (Hugo, 2019)

With its cities still growing and infrastructure under strain, embracing compact, transit-oriented development becomes essential to avoid the pitfalls of unplanned sprawl, increase accessibility, and improve overall urban travel behavior(Deevi & Karteek, 2016).

Developed V/s Developing countries

The comparison between developed and developing countries highlights fundamental differences in urban structure and travel behaviour, with examples from both global and Indian contexts. In developed countries such as the Netherlands or Japan, urban areas typically have high population densities—ranging from 3,000 to 7,800 persons/km²—and well-planned compact urban forms(Victoria Delbridge & Oliver Harman, 2022). Cities like Amsterdam, for instance, demonstrate successful integration of land use and transit, where 40–50% of trips

are made by public transport, and the average trip length is only about 5–7 km(Yenisetty & Bahadure, 2020). This is made possible by mixed-use zoning, dense street networks, and efficient public transit systems. As a result, private vehicle dependency remains low (20–30%), and overall travel satisfaction is high due to shorter commutes and better accessibility(Grazi et al., 2008),(MADHUWANTHI et al., 2016a).

In contrast, developing countries like India face significant urban challenges. Cities such as Delhi, despite high overall densities, have sprawled and uncoordinated growth patterns, with densities often ranging from 1,000 to 4,000 persons/km² in peri-urban areas. Public transport use remains low, around 10–15% of total trips, due to inadequate infrastructure, poor last-mile connectivity, and mismatches between housing and job locations(See Figure 2). This leads to longer commute distances—often between 8–12 km—higher dependency on private vehicles (60–80%), and increased congestion and pollution. For instance, in Hyderabad or Mumbai, vehicle ownership and use are growing faster than public transport investments, reflecting a shift toward unsustainable travel behaviour(Bertaud, n.d.),(Kotharkar & Bahadure, 2019). These disparities highlight the urgent need for compact urban development strategies in Indian cities to reduce travel distances, enhance public transport usage, and improve overall mobility experience(Dempsey et al., 2008).

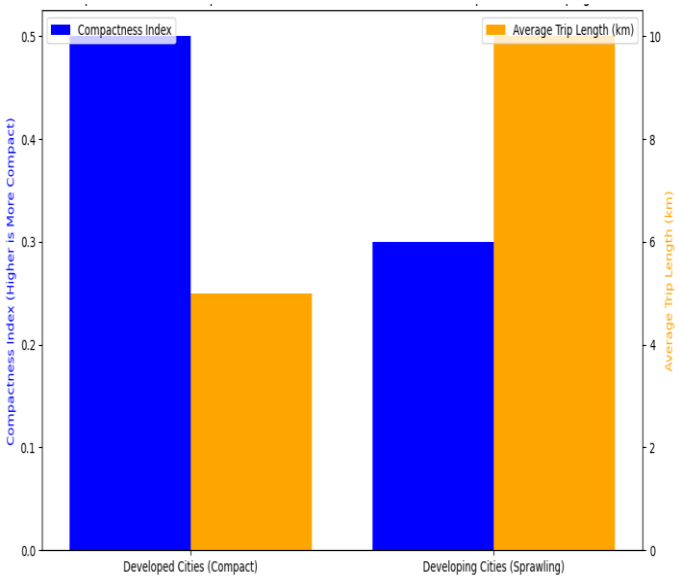


Figure 2- Comparison of Urban Compactness and Travel Behavior Between Developed and Developing Cites (Source – Author)

1.2 Need of the study

India is undergoing a transformative phase of urbanization, with over 35% of its population now residing in urban areas, and projections indicating a sharp rise in the coming decades. While urban growth is a sign of economic development, the current pattern of this growth—characterized by sprawling, low-density, and uncoordinated expansion—poses serious challenges to sustainable mobility. Unlike compact cities where land use and transport systems are well-integrated, many Indian cities are witnessing dispersed development, leading to spatial mismatches between residences, workplaces, and essential services.

This disjointed urban form has a direct and profound impact on travel behavior. As cities expand horizontally without a clear structure or hierarchy, the average trip lengths increase significantly, particularly for work and education-related travel. The efficiency of public transport networks declines in such sprawled environments, as low-density development limits the viability of high-frequency, mass-transit systems. This leads to an increasing reliance on private motorized vehicles, which in turn contributes to traffic congestion, longer travel times, rising fuel consumption, and environmental degradation.

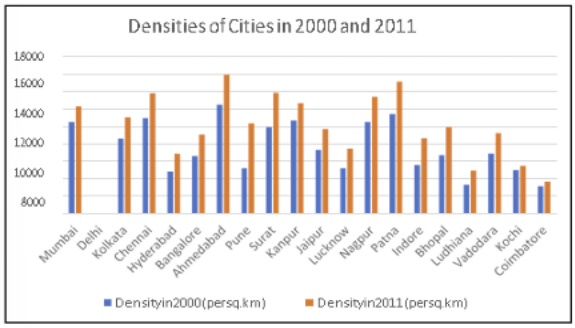


Figure 3-Densities of Cities in 2000 and 2011(Verma & Kumar, n.d.)

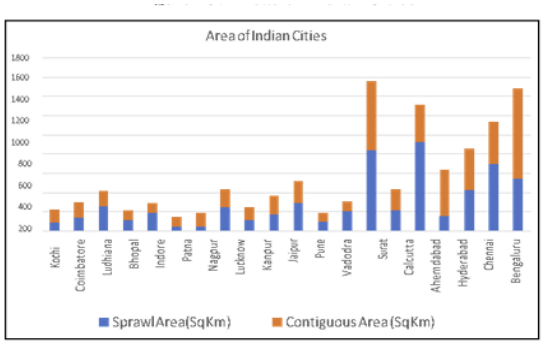


Figure 4-Sprawl and Contiguous Area of Indian Cities(Verma & Kumar, n.d.)

Situation of Indian Cities

India's population increased substantially between 2001 and 2011; urban land expanded at an even faster rate. It leads to longer commutes, higher car dependence, and increased infrastructure costs(Verma & Kumar, n.d.).This pattern of growth not only raises economic burdens but also diminishes walkability and livability within urban environments.

A majority of Indian cities, including Mumbai, Delhi, Chennai, Hyderabad, Bengaluru, Ahmedabad, Pune, and Patna, have experienced a notable rise in population density between

2000 and 2011, indicating intensified urban development and vertical growth (Refer Figure 3). Cities like Ahmedabad and Patna witnessed some of the sharpest density increases, driven by rapid urbanization, economic growth, and migration toward employment hubs.

Simultaneously, cities such as Bengaluru, Chennai, Hyderabad, Ahmedabad, and Surat have expanded significantly in both contiguous and sprawl areas, reflecting unregulated horizontal growth. Bengaluru, in particular, shows the largest contiguous urban footprint, followed by Hyderabad and Chennai—highlighting the mounting pressure on land resources and the urgent need for integrated spatial planning (Refer Figure 4). The rise in sprawl areas points to fragmented urban growth patterns, often driven by suburban development, lack of compact planning, and insufficient land use controls. This has implications for transport efficiency, infrastructure costs, and environmental sustainability(Verma & Kumar, n.d.).

Rapid motorization in Indian cities—especially in metros like Hyderabad and Delhi—has outpaced population growth, intensified congestion and straining inadequate road infrastructure (ReferFigure 5). Most cities have a road density below 2.0 km/km², highlighting weak network coverage and limited capacity. Simultaneously, a significant portion of urban trips (69%) are under 5 km, yet poor land use planning has led to fragmented development and high vehicle dependence(Verma & Kumar, n.d.).

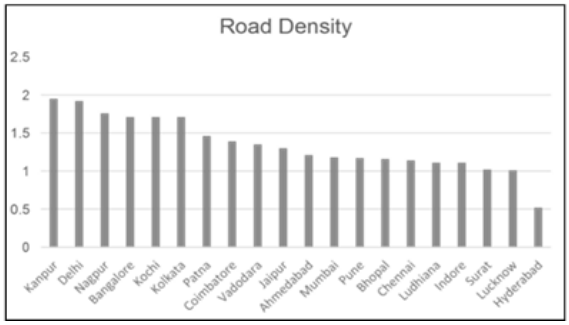


Figure 5- Road Density(Verma & Kumar, n.d.)

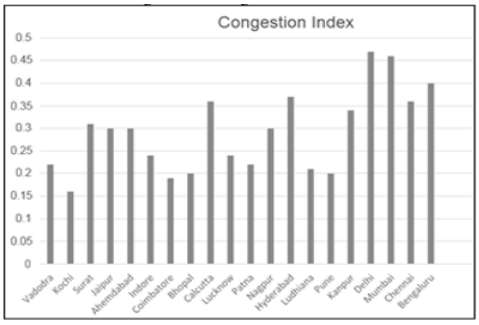


Figure 6- Congestion Index(Verma & Kumar, n.d.)

Commute patterns reflect inefficiency: average trip distances remain short, but last-mile connectivity is weak, and public transport usage is low due to poor accessibility and a mismatch between housing and job locations. The congestion index remains high in most cities, further emphasizing the need for efficient spatial strategies (Refer Figure 6).

In this context, promoting **compact urban form**—characterized by higher density, mixed

land use, and transit-oriented development—can reduce travel distances, enhance non-motorized and public transport usage, and improve overall mobility efficiency (Refer Figure 7). For India, where infrastructure is overstretched and urban sprawl is unchecked, compact city development offers a critical pathway to sustainable, accessible, and equitable urban mobility(Verma & Kumar, n.d.),(Angel et al., 1990a).

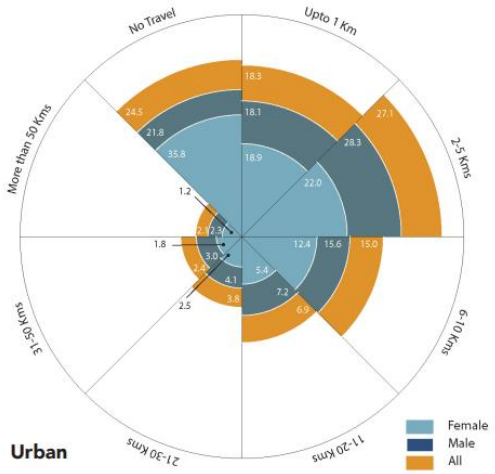


Figure 7- Modal Split of Urban India(Geetam Tiwari, 2048)

1.3Aim

To study how compactness in urban form can help in improving the travel behavior.

1.4 Objectives

1. To investigate how compact urban form (density, built-up, network) influences travel behavior.
2. To identify key indicators and parameter that effectively assess the relationship between compactness and intra-city travel behavior that, including mobility metrics and shape indices.
3. To use various analytical methods to evaluate gaps and relations among the identified indicators related to compactness and travel behavior for the selected study area,
4. To create a comprehensive framework that examines how spatial equity influences access to public transit and amenities, and how this access subsequently affects travel behavior within urban areas.
5. To suggest planning interventions and recommendations to improve the compactness

which lead to improving the travel behaviour of the city.

1.5 Scope

1. The study will analyze key factors such as urban compactness, density, and mixed land use in relation to travel behavior.
2. The study will indicate that cities with compact development patterns experience lower VMT, contributing to decreased traffic congestion and improve the pedestrian friendly infrastructure.
3. The study will focus on understanding how spatial expansion affects intra-urban transportation emphasizing the importance of integrating land use and transport planning to promote efficient travel behaviors.

1.6 Limitations

1. The study will primarily focus on quantitative data and statistical analysis, potentially overlooking the qualitative aspects of travel behavior, such as personal motivations, income that can significantly impact transportation choices.
2. The defining and measuring compactness involve subjective metrics.

1.7 Methodology

This study assesses the impact of compact urban form on travel behavior through a detailed evaluation of key spatial and mobility indicators. Drawing from relevant literature and global case studies, ideal values for each indicator are established to form a five-point benchmarking scale. The indicators cover critical dimensions such as population and built-up density, urban form, accessibility to transit, and actual travel behavior patterns. These helps in identification of gaps of the study which can be further used in making recommendations.

Nashik City is chosen as the case study area due to its rapid urban expansion and emerging transit infrastructure. Each selected indicator is measured and evaluated against the benchmark to determine current performance levels. A composite index is then derived using a geometric mean method, providing a consolidated measure of urban compactness and its influence on travel choices.

The scoring and analysis not only highlight strengths and weaknesses in Nashik's existing urban structure but also reveal spatial and policy-level gaps. These insights are used to recommend context-specific strategies aimed at enhancing compact development, promoting sustainable mobility, and informing future urban planning efforts. This approach offers a replicable framework for other mid-sized cities facing similar urbanization and mobility challenges.

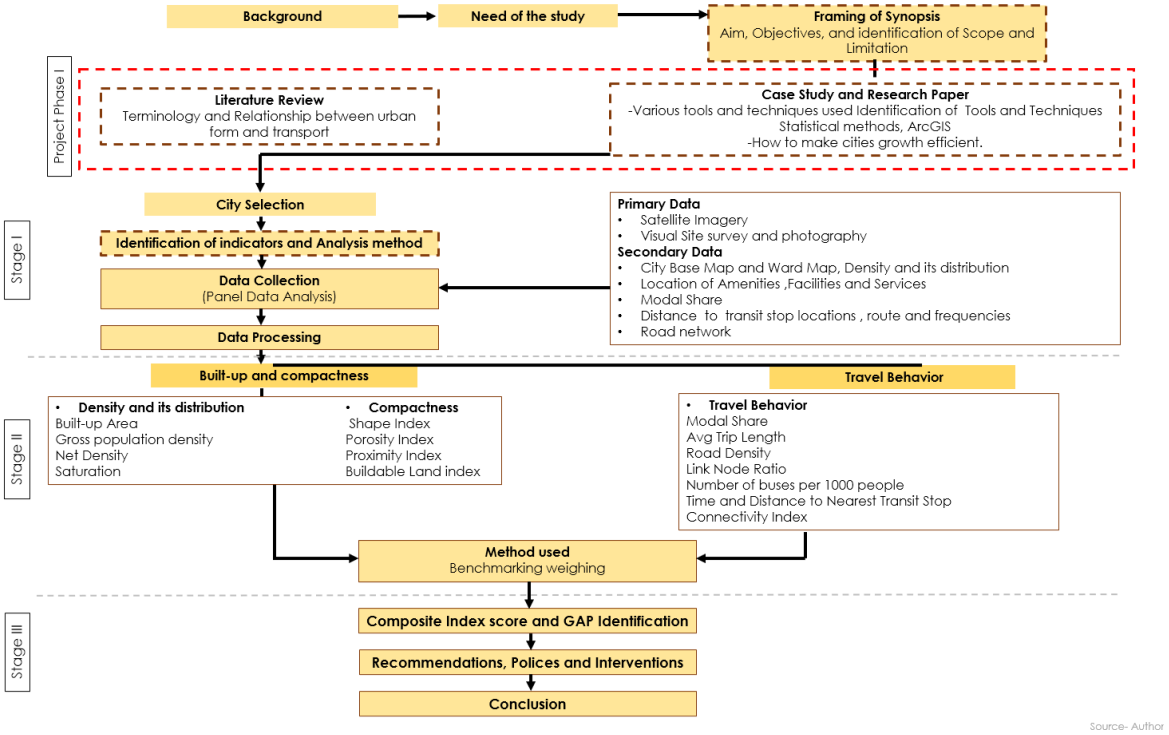


Figure 8-Methodology of the study (Source – Author)

Chapter -2
Literature Review

Urban form elements play a critical role in shaping both the compactness of a city and the travel behavior of its residents. These elements—such as density, land use mix, street connectivity, and urban layout—not only define the physical structure of the city but also influence how people interact with the built environment(Angel & Lamson-hall, 2020).

As cities continue to grow, the spatial structure and organization of the built environment play a pivotal role in shaping how people move within urban areas. Compact urban forms, characterized by higher density, mixed land uses, and enhanced connectivity, influence travel patterns by reducing distances, improving accessibility, and promoting the use of sustainable modes of transport. Understanding this relationship is essential for urban planners and policymakers aiming to create cities that are both efficient and liveable. By analysing key indicators of compactness and mobility, this chapter provides insights into how spatial planning can directly impact travel behaviour, reduce dependence on private vehicles, and encourage more sustainable and inclusive transport choices.(Kotharkar & Bahadure, 2019),(Rahman et al., 2022).This chapter explores how key urban form elements influence compactness and travel behavior, underpinning sustainable urban development.

2.1. Compactness

It refers to a development model that emphasizes high-density living, mixed land uses, and efficient use of space within urban areas. The concept aims to create urban environments where residential, commercial, and recreational spaces are in close proximity, thereby promoting accessibility and reducing reliance on automobiles. The indicators of analyzing compactness are-

2.1.1 Density

Urban density, defined as the concentration of individuals, structures, or activities within a specific area, plays a pivotal role in shaping urban configurations. It influences transportation patterns, infrastructure development, and environmental sustainability. Density serves as a crucial measure of a city's compactness, affecting land use efficiency, transportation systems,

and ecological balance. Higher urban density enables cities to accommodate more residents within limited geographic areas, reducing the need for outward expansion into rural landscapes and supporting the formulation of effective urban development policies(Angel et al., 2021),(Dempsey et al., 2008).

Density can be categorized into three types:

1. Urban Density
2. Built-up Density
3. Density Distribution

Urban Density

Urban density refers to the average concentration of people within a defined geographic area. It increases when the population grows at a faster rate than the physical expansion of the urban area [17].

$$\text{Urban Density} = \text{Population} / \text{Urban Extent} \quad \text{.....(1)}$$

Built-up Density

Built-up density represents the average population distribution within the developed or built-up portions of a city, excluding open spaces.

$$\text{Built-up Density} = \text{Population} / \text{Built-up Area} \quad \text{.....(2)}$$

This metric offers a more focused view of population distribution within constructed areas compared to broader urban density, which includes both built-up and open spaces. Built-up density is typically higher than urban density because it uses a smaller denominator, excluding undeveloped land and open areas.

Density Distribution

Density distribution describes the variation in density across a city based on the distance from the city center. It explains how population, buildings, or land use intensity change as one moves outward, highlighting patterns of urban expansion and spatial organization. Density declines sharply with the increase in distance from the city center and represents a spread-out city.

2.1.2 Buildable Land Index

It measures the proportion of the city's urban extent that is located within a Buildable Land

Circle centered at the centroid of the urban extent. This index focuses on land that is suitable for development.

Buildable Land Index= Area of Urban extend within buildable land circle/ Total Urban Area……..(3)

Where,

Area of Urban Extent within Buildable Land Circle: This represents the total area of the city's urban extent that lies within the boundaries of the Buildable Land Circle centered at the centroid.

Total Urban Area: This is the overall area of the city's urban extent(Angel et al., 2021).

High Buildable Land Index: Indicates that a significant portion of the city's urban extent is within the Buildable Land Circle, suggesting ample land available for development, which facilitates urban growth and accommodates population increases.

Low Buildable Land Index: Signifies that a smaller proportion of the city's urban extent falls within the Buildable Land Circle, indicating limited availability of suitable land for development, which can constrain urban growth and lead to increased competition for available land(Angel et al., 1990b).

2.1.3 Saturation

It is the urban extent of the city consists of both open spaces and built-up areas. Saturation is defined as the ratio of the built-up area of a zone (or a city) and its extent. Saturation varies between the values of 0 and 1. It approaches 0 when the proportion of urbanized open space within the urban environment is significantly greater than the proportion of constructed areas; conversely, it approaches 1 when the proportion of urbanized open space is markedly lower than that of the built environment(Angel, 2023).

Saturation = Built-up area / Urban Extent……...…….(4)

2.1.4 Porosity Index

It refers to the amount and distribution of open or undeveloped spaces within the built-up fabric of a city. It is an important spatial indicator in compactness studies because it reveals how continuous or fragmented the urban form is. A higher value indicates more open or

unbuilt space so less compact growth whereas a lower value shows more continuous built-up area suggest a more compact growth(Angel et al., 1990a).

2.1.5 Shape Index (Perimeter to area Ratio)

The perimeter-area ratio (PARA) is a measure of the complexity of a shape, and can be used to evaluate the efficiency of different shapes.

$$PARA = P/A \quad \text{.....(5)}$$

A lower PARA value indicates a more compact shape, while a higher PARA suggests a more complex or irregular shape. For example, a square has a lower perimeter-area ratio compared to a highly convoluted shape with the same area, indicating that it is more efficient in enclosing space.

Size Dependency: A key limitation of the perimeter-area ratio is that it depends on the size of the shape being analyzed. As a polygon increases in size while keeping its shape constant, the PARA changes. This can lead to misleading conclusions if the results are not standardized.

Shape Complexity: While PARA offers insights into how efficiently a shape uses space, it does not account for all aspects of shape complexity. To gain a more complete understanding, other metrics, such as fractal dimension or compactness ratio, may be necessary(Angel et al., 1990b).

2.1.6 Contiguity Index

It is the extent to which the footprint of the city is not fragmented into a large number of freestanding urban clusters, measured as the share of the urban extent of the city in the largest contiguous urban cluster.

Contiguity Index-Area of Largest Contiguous Urban Cluster / Total Urban Extent Area….(6)

Low contiguity can result in isolated communities that lack access to essential services and social networks, potentially exacerbating issues related to inequality and accessibility as it increases travel distance(Angel et al., 2021).

2.1.7 Dispersion Index

It measures the degree of urban sprawl or the lack of concentration in built-up areas. A high dispersion index indicates that built-up areas or population are unevenly distributed—typically in isolated patches—leading to longer travel distances, reduced accessibility, and increased dependence on private vehicles higher dispersion index indicates greater spatial spread and lower compactness, typically associated with urban sprawl. Conversely, a lower dispersion index suggests that development is more concentrated and cohesive—an indicator of a compact urban form.(Angel et al., 1990a).

2.1.8 Land use density

It refers to the intensity or concentration of a specific land use type—most commonly residential, commercial, or mixed-use—within a defined spatial area. Higher land use density supports compactness and sustainable travel (more walkable, transit-friendly areas) Typically measured as population per hectare (residential density) or built-up area per unit of land (floor area ratio or building coverage), higher land use density supports efficient utilization of infrastructure and services(Angel et al., 2021).

2.2 Travel Behavior

Travel behavior encompasses the patterns and decisions individuals make concerning their travel activities. This includes choices about the mode of transportation, timing, destinations, and travel companions, as well as the underlying motivations for these decisions(MADHUWANTHI et al., 2016b).

The various factors that influence travel behavior are-

1. Commuting Patterns: High-density, mixed-use areas support shorter commutes and promote sustainable modes like walking, cycling, and transit.
2. Trip Purpose: Proximity of residential, commercial, and recreational uses reduces travel distance for daily needs.
3. Mode Choice: Walkable urban form and robust public transit networks encourage non-

motorized and public transport use.

4. Trip Frequency & Length: Compact urban design leads to more frequent but shorter trips, unlike dispersed suburban settings.
5. Social Interaction: Pedestrian-friendly spaces foster social engagement and active travel.
6. Environmental Awareness: Urban forms emphasizing green infrastructure and connectivity encourage eco-conscious travel choices (Li et al., 2024a).

The indicators of analyzing travel behavior are-

2.2.1 Avg Trip Length per person

The mean distance traveled per trip is a key measure of urban spatial structure and travel behavior, typically expressed in kilometers. Shorter trip distances generally indicate a compact urban form with well-integrated land uses, facilitating easy access to services and reducing travel times, costs, and environmental impacts. Identify an ideal mean trip distance of 3 to 6 km for compact cities, characterized by high density and mixed land uses, while mid-size cities typically exhibit longer average trips ranging from 5 to 8 km due to more dispersed land uses and greater reliance on motorized transport. It refers to the mean distance traveled per trip by individuals within a city or region, typically measured in kilometers (km). Ideal range for compact city is 3-6 km, mid-size city -5-8 km(Maharjan et al., 2018).

2.2.2 Modal share

Modal share represents the percentage distribution of different transportation modes used by a population within a specific area, reflecting travel behavior and preferences. A balanced modal share is vital for a self-sustaining urban transport system, with public transport ideally comprising 30 to 40 percent of total trips. This level supports reduced congestion, lower emissions, and greater accessibility, indicating an effective and sustainable transit network. (Yenisetty & Bahadure, 2020).

2.2.3 Link- Node Ratio

It assesses the connectivity and efficiency of a road network in urban areas. It is calculated

by dividing the total number of street segments (links) by the total number of intersections or endpoints (nodes). A higher ratio indicates better connectivity and lower ratio indicates poor connectivity with many dead ends and disconnected streets(Rode et al., 2017).

2.2.4 Intersection Density

It is defined as the number of intersections (nodes where streets meet) per unit area, typically per square kilometer or hectare. A higher intersection density implies a well-connected street grid, which facilitates shorter travel distances, encourages walking and cycling, and improves accessibility to public transport. Conversely, low intersection density often indicates a disconnected, sprawling urban form that increases reliance on private vehicles(Li et al., 2024b).

2.2.5 Road Density

It measures the total length of roads within a given area. It reflects the intensity and extent of the road network, providing insight into the level of infrastructure development and accessibility within a city. A higher road density generally indicates a well-connected and accessible urban area, supporting efficient movement, reducing travel times, and enabling better access to public transport, services, and amenities(Chen et al., 2024).

2.2.6 Proximity index

It measures the degree of spatial closeness or accessibility of urban elements between land uses or urban functions, making it a crucial indicator in compact city planning, accessibility studies, and travel behavior analysis. A higher Proximity Index suggests that essential services and destinations are located closer to where people live, which supports shorter trip distances, walkability, and greater use of public transport(Angel et al., 1990a).

2.2.7 Transit Stop Density

It refers to the number of public transits stops (bus, metro, etc.) per unit area, usually expressed as stops per square kilometer. It is a key indicator of public transport accessibility and plays a major role in shaping travel behavior, especially in promoting public and non-motorized transport use. Transit stops should ideally be within 400–600 meters of most residences or

destinations(Prestes et al., 2022).

2.3 Relationship between Compactness and Travel Behavior

Urban compactness plays a critical role in shaping travel behaviour by influencing the spatial arrangement of land uses, density, and connectivity within a city. A compact urban form, characterized by higher densities, mixed land use, and well-integrated transport networks, inherently reduces the physical distance between origins and destinations. This spatial proximity encourages residents to choose active and public modes of transportation over private vehicles.

Moreover, compact urban areas typically support greater accessibility to essential services and employment opportunities, which enhances the efficiency of travel and reduces overall trip lengths. This urban structure not only promotes walking and cycling but also improves the viability and coverage of public transit systems due to concentrated demand.

In contrast, low-density, sprawling developments often lead to increased reliance on private vehicles and longer travel distances, thereby contributing to higher energy consumption and emissions. By minimizing travel demand and fostering sustainable mobility choices, compact urban forms directly support the goals of efficient, inclusive, and environmentally responsible urban development.

2.4 Assessment Indicators and its Benchmarking

The indicators provide measurable parameters that help quantify the efficiency, accessibility, and sustainability of compact urban form and mobility patterns.

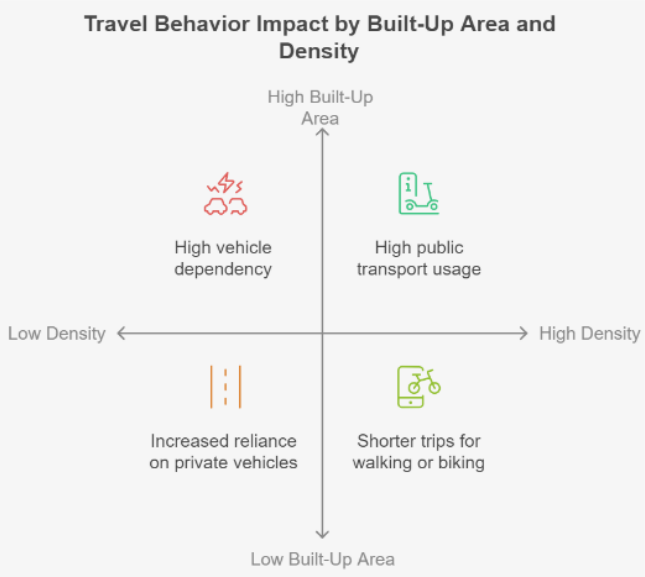

Travel Behavior Impact by Built-Up Area and Density
High Built-Up Area
High vehicle dependency
High public transport usage
Low Density
High Density
Increased reliance on private vehicles
Shorter trips for walking or biking
Low Built-Up Area

Figure 9- Travel Behavior Impact by Built up and Density (Source – Author)

Table 1- Compactness Indicators

Indicator	Measure	Influence on Travel Behaviour	Relevance	Source
Population Density	Net Density- People per developed land. Gross Density- People per total land area.	Higher Density: Short trips, walking/cycling/transit. Lower Density: More cars, longer commutes.	Determine public transport need.	(Ewing & Cervero, 2010), (Bertaud, 2001)
Built-up Density	% of built-up area per unit of land.	High Density: Mixed-use, shorter trips. Low Density: Sprawl, more travel.	Reflects intensity of land use.	(Talen, 2003), (Angel, 2012)
Buildable Land Index	Area of Buildable land / Total area X 100	Lots of buildable land + spread-out development = low density, more travel, more cars.	Identifies growth potential	(Angel, 2012), (Bhatta, 2010)
Saturation	Ratio of actual built-up area to the maximum allowable density.	High Saturation (Dense): Public/non-motorized transport. Low Saturation (Underutilized): More cars.	Indicates land consumption efficiency	(Bhatta, 2010), (Phelps, 2006)
Porosity Index	Open Area / Total Area	High porosity - fragmented areas, bad for walking/transit.	Identifies urban sprawl patterns	(Tsai, 2005), (Galster et al., 2001)
Shape Index	Perimeter / Area	Compact cities - Less car use; Irregular cities - more cars.	spatial morphology	(Angel, 2012), (Bertaud, 2001)
Contiguity Index	Area of contiguous (clustered) development/ Total Area	Clustered development - better walking & transit.	Measures spatial cohesion	(Galster et al., 2001)
Dispersion Index	Average distance per person to the center of gravity /Avg distance to center of circle of similar built up/developed area	Spread-out development - more cars, longer trips.	Detects sprawl patterns	(Tsai, 2005)

Land-Use (% of road)	Ratio of different land uses per unit area (e.g., residential, commercial, institutional).	High Density: Walkable, short commutes. Low Density: Car-dependent, long commutes.	Evaluates functional intensity	(Angel, 2012)

Table 2 - Travel Behavior Indicators

Indicator	Measure	Influence on Urban Form	Relevance	Source
Travel Behaviour				
Average Trip Length per person	Trip Distance / Number of Trips	Compact cities = shorter trips.	Compact, mixed-use areas = shorter trips, more walking/transit.	Ewing et al. (2002)
Mode Share	Trips By a Specific Mode / Total trips X 100	Higher compactness – more walking, cycling, and public transit mode shares.	Dense, mixed-use, connected areas = less cars, more walking/transit.	Newman & Kenworthy (1999)
Link – Node Ratio	Number of Road Segments (Links)/ Number of Intersection (Nodes)	High ratios = grid network = walkable, compact design.	High link-node ratio = better connectivity = more walking/cycling/transit, shorter trips.	Berrigan et al. (2010)
Intersection Density	No of Intersection/ Area	More intersections = more walking/cycling, less cars	More intersections = better walking, more travel options.	Cervero & Kockelman (1997)
Road Density	Total Road Length/ Area	Dense roads can mean car-focused planning, depending on how connected they are.	Dense roads can shorten trips, but car-focused design can still encourage driving even in compact areas.	Cervero & Kockelman (1997)
Proximity Index of PT	Distance to amenities	Short distances = more walking/cycling/transit.	Accessibility = Closeness of jobs, shops, and transit to homes.	Angel et al. (2010)
Transit Stop Density	Number of Transit Stops / Urban Area	Many transit stops = compact, transit-friendly area.	More transit stops = better access, less car use, more transit riders.	Geurs & van Wee (2004)

These Table 1 and Table 2 indicators are studies from the research papers and are shortlisted on the basis of the influencing factors for the spatial analysis. These indicators need to be normalized in order to group all indicators scores into a composite index score.

2.4.1 Benchmarking of the Indicators

Benchmarking urban mobility and travel indicators helps cities understand how people move and how well their transport systems are working. Indicators like trip frequency, proximity, PKT, VKT, public transport use, and congestion levels offer a clear picture of mobility trends and challenges(Kotharkar & Bahadure, 2019).Table 3 presents a benchmarking for evaluating urban form, emphasizing through benchmarking standards and numerical scoring (1-5)(Shastry, 2010).

Table 3- Benchmarking for the compactness indicators

Indicator	Ideal Range	5(Very Good)	4(Good)	3(Moderate)	2(Poor)	1(Very Poor)	Sources
Population Density (Gross Density)	100-150 pph	100-150 pph	70-100pph	50-70 pph	50-70 pph	<50pph	(URDPFI Guidelines, 2015)
Built-up Density	60-40%	>70%	60-70%	40-60%	20-40%	<20%	(URDPFI,Smart Cities Mission Toolkit)
Buildable Land Index	0.8-0.6	>0.80	0.7-0.8	0.5-0.7	0.3-0.5	<0.3	(McKinsey Urban India Report 2010; NITI Aayog Urbanization Strategy)
Saturation	60-70%	70-85%	60-70%	50-60%	40-50%	<40%	(Master Plans of Pune, Surat; URDPFI Guidelines)
Porosity Index	0.25-0.35	0.25-0.35	0.36-0.45	0.46-0.55	0.56-0.65	>0.65	(National Urban Transport Policy, 2014; URDPFI)
Shape Index (Perimeter to area ratio)	12-15(Lower the better)	<0.2	0.2-0.4	0.4-0.6	0.6-0.8	>0.8	(Landscape Metrics Studies; Angel Shlonsky's Urban Form Study)
Contiguity Index	>0.75	>0.75	0.65-0.75	0.5-0.65	0.3-0.5	<0.3	(Herold et al., 2003; Angel 2011 Metrics)
Dispersion Index	1.2-1.5	<1.2	1.21-1.5	1.5-1.81	1.81-2.2	>2.2	NIUA Report
Land-Use (% of road)	12-15%	12-15%	9-11.9%	6-8.9%	4-5.9%	<4%	(World Bank TOD Reports 2017; Delhi TOD Policy 2017)

Table 4-Benchmarking for the Travel Indicators

Indicator	Ideal Range	5(Very Good)	4(Good)	3(Moderate)	2(Poor)	1(Very Poor)	Sources
Avg Trip Length per person	<3 km (compact cities with efficient public transport)	0-3 km	3-5km	5-8km	8-10 km	>10 km	"Urban Mobility India" report by Ministry of Urban Development, India (2011)
Modal Split	>40% trips by public transport	>40% public transport	30-40% public transport	20-30% public transport	10-20% public transport	<10% public transport	"Transport for Sustainable Development in India" by the World Bank (2013)
Link Node Ratio	>2.5	>2.5	2.0-2.5	1.5-2.0	1.0-1.5	<1.0	Harris, C. D., & Ullman, E. L. (1945). "The Nature of Cities"
Road Density	>3 km of roads per square kilometer	>3 km/km²	2.3-3 km/km²	2-2.5 km/km²	1.5-2km/km²	<1.5 km/km²	"Urban Transport in India: Challenges and Opportunities" by the World Bank (2013)
Transit Density	>5 transit stations per square kilometer	>5 stations/km²	4-5 stations/km²	3-4 stations/km²	2-3 stations/km²	<2 stations/km²	Geurs, K. T., & van Wee, B. (2004). "Accessibility Evaluation of Land-use and Transport Strategies"
Public Transit Coverage	80-65%	>80%	65-80%	50-65%	30-50%	<30%	World Bank Urban Mobility Diagnostics(India,2021)
Proximity Index of PT(within 500m)	>80%	>80%	70-80%	50-70%	30-50%	<30%	Gordon, P., & Richardson, H. W. (1997). "Are Compact Cities a Desirable Goal?"

These(Table 4) benchmark values are typically derived from best practices, empirical studies, or planning guidelines, and reflect optimal performance levels in terms of urban compactness and sustainable travel behavior. To facilitate systematic evaluation, a five-point rating scale is employed by comparing the observed value of each indicator against its corresponding benchmark. This method categorizes performance from very low to very high, providing a nuanced understanding of how effectively an urban area aligns with desired planning objectives.

2.4.2 Weighting of Indicators

Weighting and aggregation systems have a decisive effect on the outcome of the Composite Index. Weights used in calculation of composite indicators can have a tremendous influence on the final composite indicators and its results. A number of composite indicators utilize equal weighting, which allocates the same weight to each component.

2.4.3 Composite Index Score

A composite index score represents overall performance by combining multiple indicators into a single, standardized value (Chakrabartty, 2017). Aggregation methods commonly used include linear (arithmetic) and geometric (multiplicative) techniques. While linear aggregation allows compensation between indicators—potentially masking poor performance—geometric aggregation reduces this effect, offering greater accuracy. Therefore, geometric aggregation is adopted in this framework to derive the composite index score, ensuring a more balanced and reliable assessment (Gan, 2017).

$$\textbf{Composite Score} = \sqrt[n]{\textbf{(Product of Scores of All Indicators)}} \quad \ldots\ldots\ldots (7)$$

These indicators and analytical tools play a crucial role in identifying spatial and policy-level gaps within the urban fabric. By assessing various aspects of compactness—such as density, land use mix, accessibility, and connectivity—and correlating them with travel behavior patterns, the study highlights areas where the existing urban form is inefficient or unsustainable.

Chapter -3
Study Area

3.1 Selection of Study Area

Seven medium size Indian cities selected for evaluation are Nashik, Vadodara, Pune, Rajkot, Bhopal, Thiruvananthapuram and Coimbatore. The indicators focus on compactness and transportation-related land use, looking at factors like total area, built-up area, population density, and transport infrastructure to understand each city's mobility and planning needs.

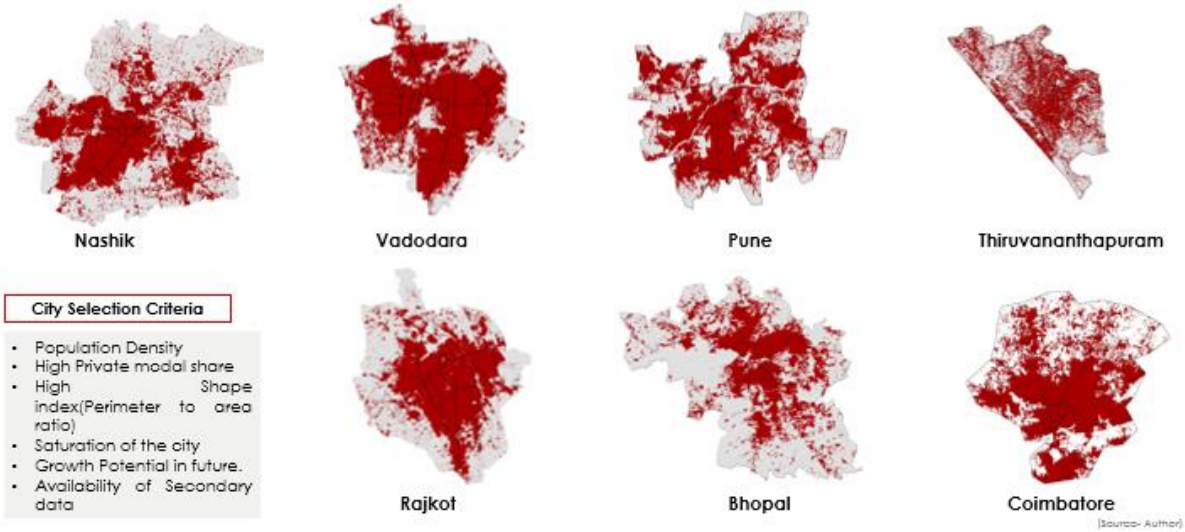


Figure 10- Built-up Densities Pattern of Various cities (Source – Author)

Density and its distribution

Table 5- Various compactness criteria of Urban Form for evaluating the cities

Criteria	Nashik	Vadodara	Pune	Thiruvananthapuram	Rajkot	Bhopal	Coimbatore	Sources
Area (sq km)	267	220	350	214	161.86	463	246.8	CMP
Built-up area	114.25	161.1419	203.863	94.9858	81.123	412.0186	180.4898	Author
Population as per census 2011	14,86,053	1670806	3124458	743691	1390640	23,71,061	2136916	Census 2011
Population density (per sq km)	5565	7107	9,436	3,086	8175	5121.08	6510	Census 2011 and CMP
Saturation	0.51	0.73	0.58	0.44	0.50	0.89	0.73	Author
land area devoted to transport facility (Land use) (%)	6%	2.70%	13%	6%	3.5	10	10	CMP

Most notably, (as per Table 5) Pune has the highest density and population, followed by Bhopal with the lowest. The saturation factor, which accounts for the ratio of built-up area to the total area, shows differences in urban sprawl, with Bhopal and Nashik having higher saturation than Pune. In addition, the percentage of land area used for transport facilities, an important consideration in urban mobility, is also listed in the table. Pune invests the greatest percentage in transport(13%), and Vadodara invests the least (2.7%). The comparative statistics are necessary for learning about the varying urban issues and planning sustainable urban development strategies for each city in light of their specific attributes toward compactness and transport infrastructure. The population census statistics for 2011 serve as a benchmark for measuring population growth and its influence on urban development across time.

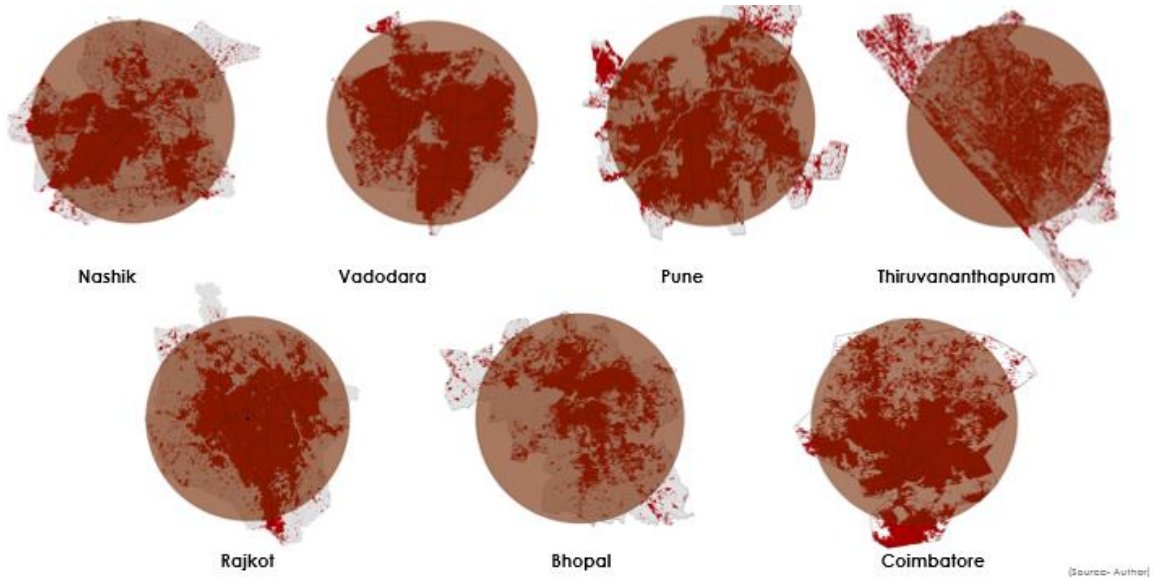


Figure 11- Relationship between Density and Area of various cities (Source – Author)

Compactness

Table 6- Criteria for Compactness

Parameters	Criteria	Nashik	Vadodara	Pune	Thiruvananthapuram	Rajkot	Bhopal	Coimbatore
Compactness	Shape Index- Perimeter to Area Ratio	0.43	0.33	0.41	0.30	0.41	0.34	0.33
	Porosity Index	0.31	0.5	0.4	0.38	0.3	0.4	0.5
	Buildable land index	0.45	0.6	0.7	0.44	0.54	0.6	0.6

The Shape Index assesses a city's compactness by measuring its circularity, where a lower value indicates a more compact urban form. Among the analyzed cities, a lower Shape Index reflects a more circular and efficient spatial structure. The Porosity Index evaluates the proportion of open or undeveloped spaces within the urban fabric, with Vadodara and Coimbatore exhibiting the highest values, signifying a more fragmented urban structure with interspersed green or vacant land. The Buildable Land Index determines the percentage of land available for development, highlighting growth potential and spatial constraints; Nashik ranks highest, indicating greater development capacity. Analyzing these indices collectively provides critical insights into urban form, balancing built and unbuilt spaces, and informing strategic urban planning for sustainable and efficient city growth. Cities like Nashik and Pune, with higher Shape Indices (0.41) and lower Porosity (0.31), support compact, walkable environments that encourage sustainable travel. In contrast, Vadodara and Coimbatore, with lower Shape Indices (0.33) and higher Porosity (0.5), show more fragmented development, often increasing car dependency. Nashik's high Buildable Land Index (0.75) also suggests strong growth potential and improved accessibility (See in Table 6).

Travel Behaviour

Table 7- Various Criteria for Travel Behavior

Parameters	Criteria	Nashik	Vadodara	Pune	Thiruvananthapuram	Rajkot	Bhopal	Coimbatore
Mode Share	Private Vehicle (%)	41.1	40	58	55	37	33	45
	IPT (auto rickshaws) (%)	19.1	14	19	14	11	3	30
	PT (Buses) (%)	6.6	6	10	21	3	32	15
	NMT (Walk, cycle) (%)	33.2	40	33	10	48	32	10
Trip Length	Average trip length in km (including walk)	4.3km	4.8	6.14	7.8	3.8	3.8	7
	Average trip length in km (excluding walk)	5.7km	7	7.5	9	6.5	6	8
Density of Road and Junction	Road length (km)	283	1068.86	950	371.94	2291	106.9	1200

As per Table 7 Pune and Rajkot show high private vehicle use, causing congestion and emissions, while Vadodara and parts of Rajkot see more walking and cycling due to compact design. Public transport use is modest but better in Bhopal and Coimbatore. Coimbatore and Nashik depend on intermediate modes for last-mile access. These trends stress the need to

boost public transit, NMT infrastructure, and last-mile connectivity for sustainable urban mobility.

3.1.1 Inferences for Selection of the Study Area

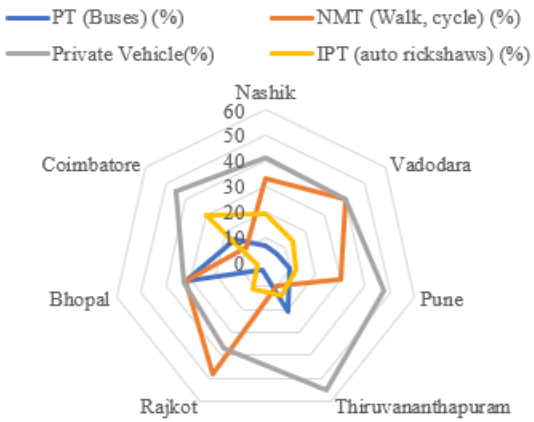


Figure 12- Modal Split of Various Cities
(Source – Author)

The analysis of seven Indian cities highlights how urban form shapes travel behaviour and mobility patterns(See Figure 12Figure 12- Modal Split of Various Cities (Source – Author). Nashik demonstrates a less compact structure with a high Buildable Land Index (0.73), moderate density (6510/km²), and strong reliance on motorized transport (40%) and intermediate public transport (20%). With the shortest average travel distance (4.9 km), Nashik supports efficient land use, accessibility, and reduced vehicle dependency. Vadodara, marked by a high porosity index (0.51), has a fragmented form, longer average trips (7.8 km), and heavy private vehicle use (58%), resulting in traffic congestion and emissions. Pune, although the densest city (9436/km²) with 13% land for transport, faces high private vehicle use (58%) due to poor public transport integration. Rajkot mirrors Pune, with high density (8175/km²) but very low NMT share (6.6%) and overdependence on private vehicles. Bhopal, with the lowest density (5121/km²) and highest saturation index (0.89), shows sprawling development and long commute distances, though its relatively high public transport usage (21%) presents improvement potential. Coimbatore has a balanced urban form with moderate density, high porosity (0.5), and good NMT/IPT usage (15% and 30% respectively), though average trip lengths remain long (7 km).

Thiruvananthapuram presents a distinct case with low population density (5565/km²), low

public transport share (14%), and the highest reliance on private vehicles (55%). Despite a relatively compact form (Buildable Land Index 0.51), inadequate transit infrastructure and low IPT/NMT usage limit sustainable travel choices.

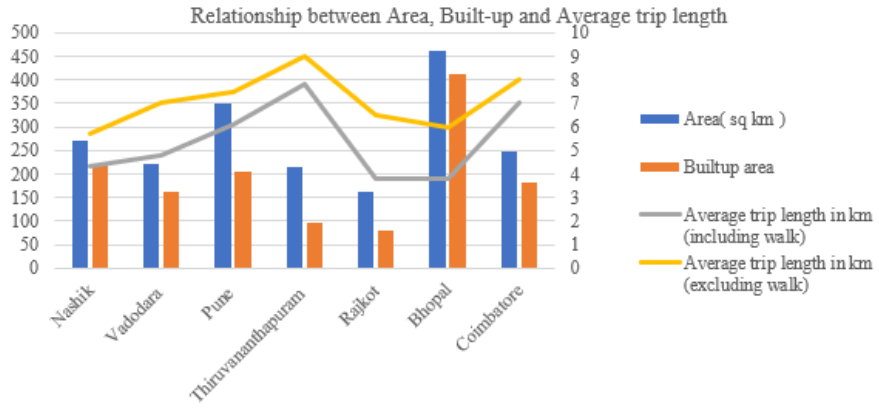


Figure 13- Relationship Between Area, Built-up and Average Trip Length (Source – Author)

Among all, Nashik demonstrates a concerning trend of urban sprawl, evidenced by its substantial built-up area expansion which correlates with increasing population density. While this growth offers development potential, it also presents challenges. The city's elongated urban form (Shape Index 0.41) contributes to longer travel distances, impacting efficiency. Although Nashik enjoys a relatively balanced average trip length (4.3 km including walk, 5.7 km excluding walk), the high reliance on private vehicles (41.1% modal share) coupled with significant intermediate public transport use (19.1% auto-rickshaws) points to potential congestion issues and a need for improved public transit. To ensure sustainable growth, Nashik must strategically manage its expansion by prioritizing efficient land use, promoting public transport, and mitigating the negative impacts of private vehicle dependence.

3.2 Nashik City -Background

Nashik is a historic and rapidly growing city in Maharashtra, India, renowned for its balanced urban development and potential for sustainable travel behavior innovations.

Population -14.86 Lakhs

Area- Approx 267 sq.km

Nashik Today is tremendously busy industrial centre. Well connected by road and rail, Nashik lies on Delhi Mumbai industrial corridor. Nashik’s key industries are localized near the village

of Ambad, Satpur and Sinnar on the Pune highway. It is the highest producer of grapes and onions and hosts over a third of India's wineries. Around 48 lakh tourists visit Nashik annually. The Nashik Municipal Corporation (NMC) is the authority responsible planning and services provision for the Nashik Metropolitan Area.

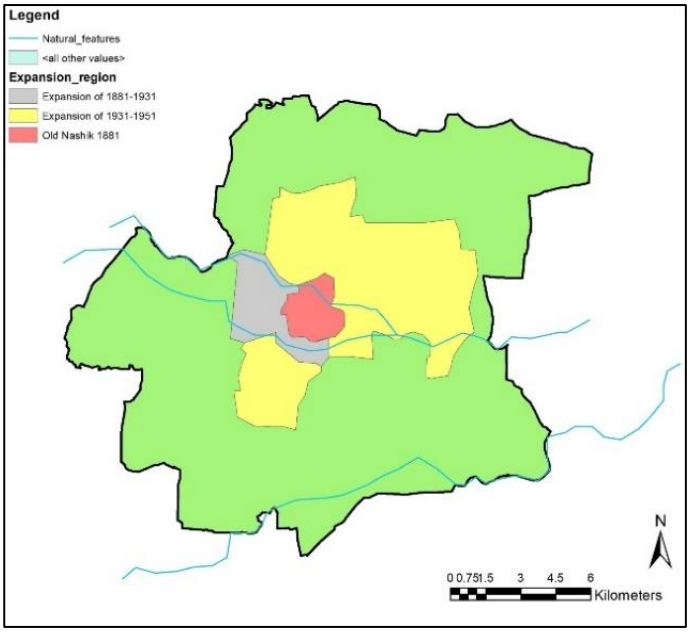


Figure 15- Growth of Nashik City (Source – Author)

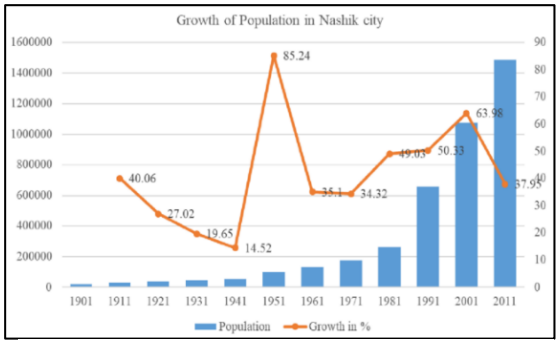


Figure 14- Growth of Population In Nashik (CDP)

Table 8-Events and its Impact on Growth of Nashik City

Year	Event	Impact on Spatial Growth
1865	Municipal Council formed	Expansion along Mumbai-Agra Highway
Late 19th Century (British Period)	Railway line built (10 km from city due to religious opposition), Tram Service introduced	New focal point formed along Nasik Road Station
1925-1928	Establishment of India Security Press and Currency Note Press	Growth towards Nasik Road Area
1947	Post-Independence era	New Residential Colonies along Mumbai-Agra Highway
1961-1981	Industrialization (MIDC Industrial Area established)	Growth towards Ambad, Satpur & Nashik Road
1979	CIDCO Established by GOM	Expansion towards CIDCO & Pathardi areas
1982 (Municipal Corporation)	Nashik becomes Metropolitan City	Expansion of Municipal limits, Population crosses 432000

1993-96	First Development Plan Formed	Peripheral expansion (Pathardi, Makhmalabad, Gangapur Road)
2005	CDP of Nashik Municipal Corporation under JNNURM	
2016	Revised Development Plan 2016-36	

Slope of Nashik

Nashik's terrain (See Figure 16) shapes its urban development potential. The central and southern areas, with gentle slopes (0–3°), are ideal for compact growth, infrastructure, and transit-oriented development. In contrast, the northern, northwestern, and southwestern edges—around Vilholi, Gangapur, and Nandurmadhmeshwar—have steep slopes (8°+), making them suitable for green buffers and water catchments rather than dense development. The eastern fringe near Katamgaon and Deolali also features hilly terrain, forming natural growth limits. This highlights the need to focus development in flatter zones while preserving steeper areas for ecological balance.

Land use

The existing land use and transport patterns in Nashik reveal signs of transport-oriented development (TOD), particularly along major highways that connect key industrial corridors such as Ambad and the Thermal Plant. These arterial routes have catalyzed linear growth and increased accessibility, supporting the movement of goods and labour between industrial hubs and the rest of the city. The Satpur MIDC and Ambad Industrial Area serve as major employment anchors, attracting a significant working population and influencing land use in adjacent areas.

However, despite this connectivity, these industrial zones remain physically and functionally detached from several residential pockets, particularly those located in older or peri-urban parts of the city. The lack of integrated planning between employment centres and housing has led to spatial mismatches, resulting in long commute distances, traffic congestion, and increased dependence on private transport. This separation also limits the potential for creating mixed-use, walkable neighbourhoods that are essential for sustainable urban development.

Table 9- Land use Split for Nashik City (Source - CDP)

Land Use Type	Percentage of Area in Nashik City
Residential	23%
Commercial	1%
Industrial	5%
Public and Semi-Public	7%
Recreational	3 %
Transportation and Communication	6%
Agriculture	33%
Vacant Land	17%

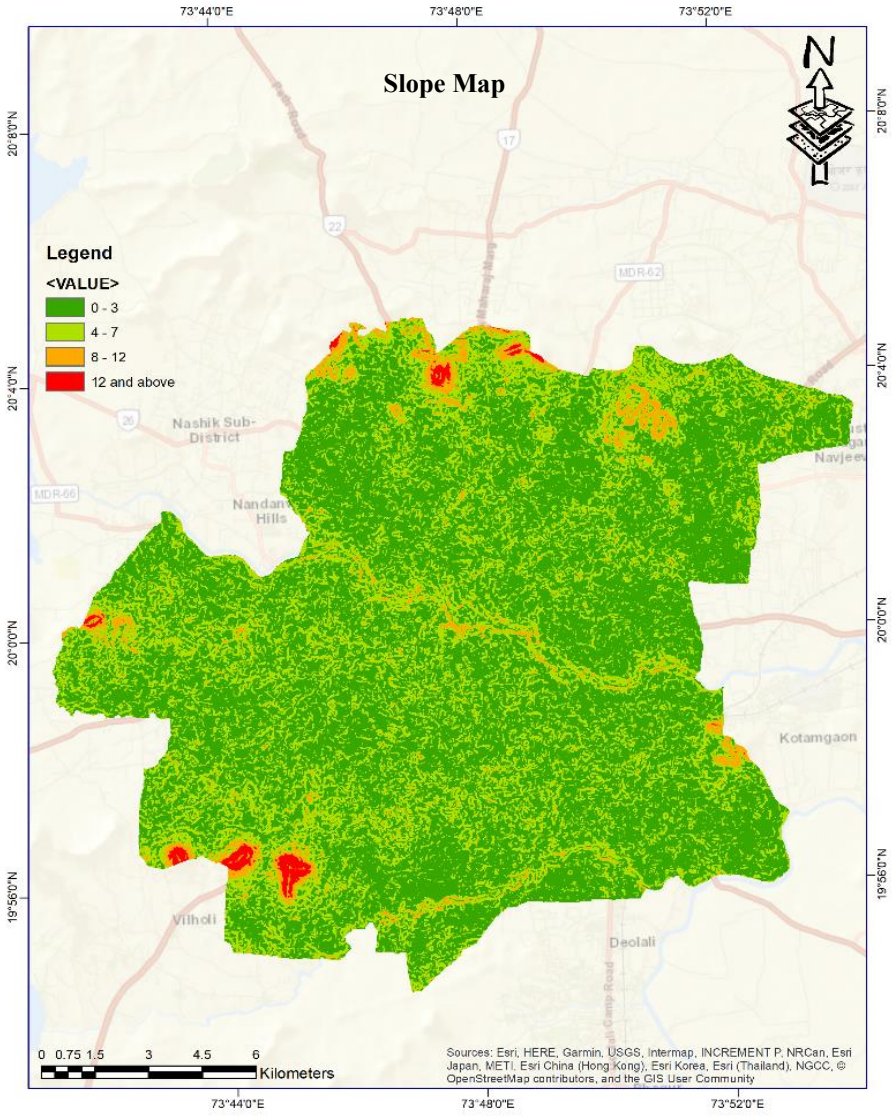


Figure 16- Slope Map of Nashik

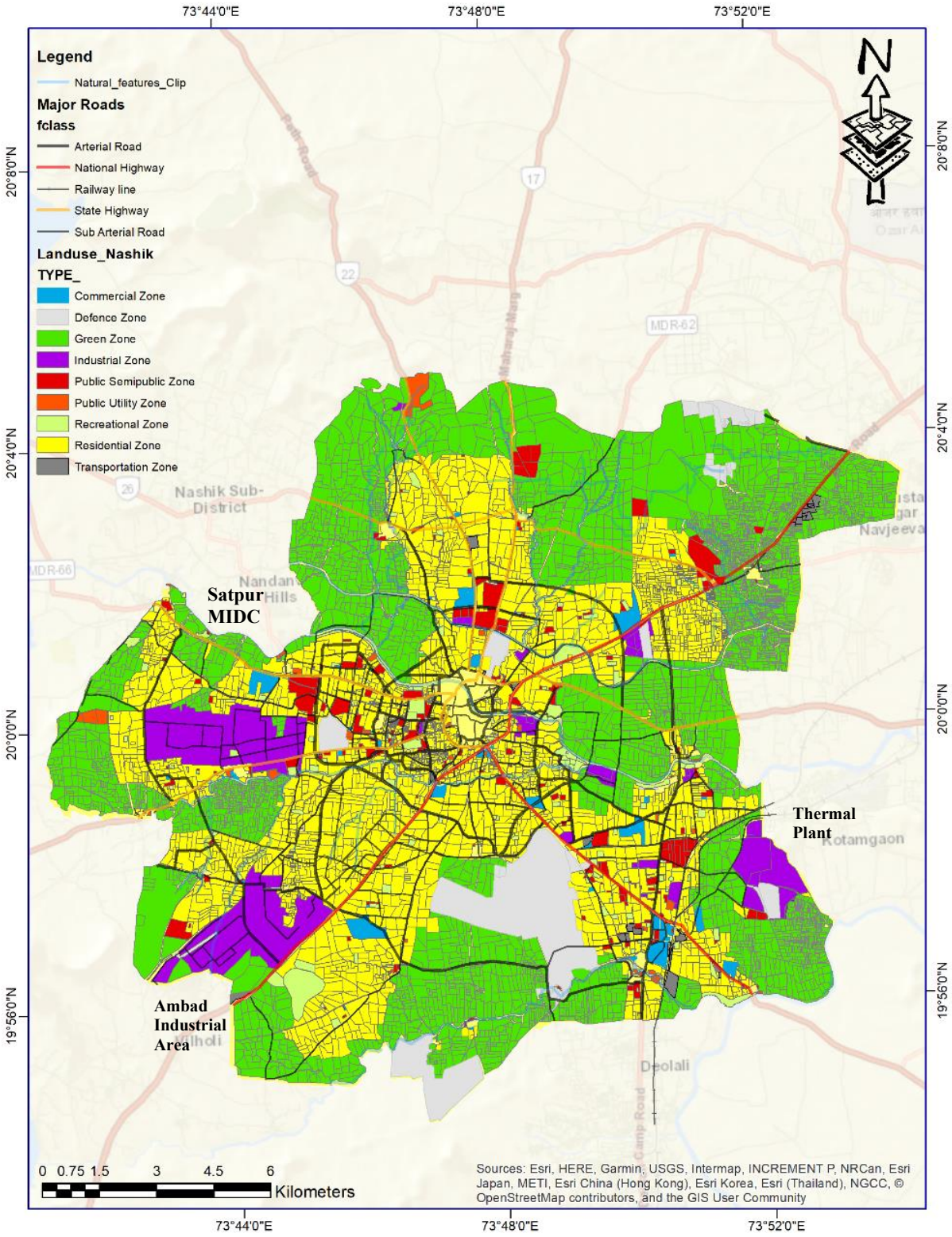


Figure 17- Land use of Nashik city

Road Network and Travel Behaviour

Nashik possesses a well-integrated road network that significantly contributes to intra-city connectivity and links the city to regional and national transport corridors. Strategically positioned at the convergence of key highways—such as National Highway 60 (Pune–Nashik) and National Highway 848 (Mumbai–Agra via Nashik)—the city functions as a vital transit node within Maharashtra. Within the urban fabric, the road system includes a hierarchy of arterial routes, ring roads, and feeder streets that enable efficient circulation. Prominent corridors such as the Mumbai–Agra Road (NH-848), Gangapur Road, and Trimbak Road act as primary arterials, supporting both public and private modes of transport. This network underpins Nashik's role as a regional hub for trade and mobility.

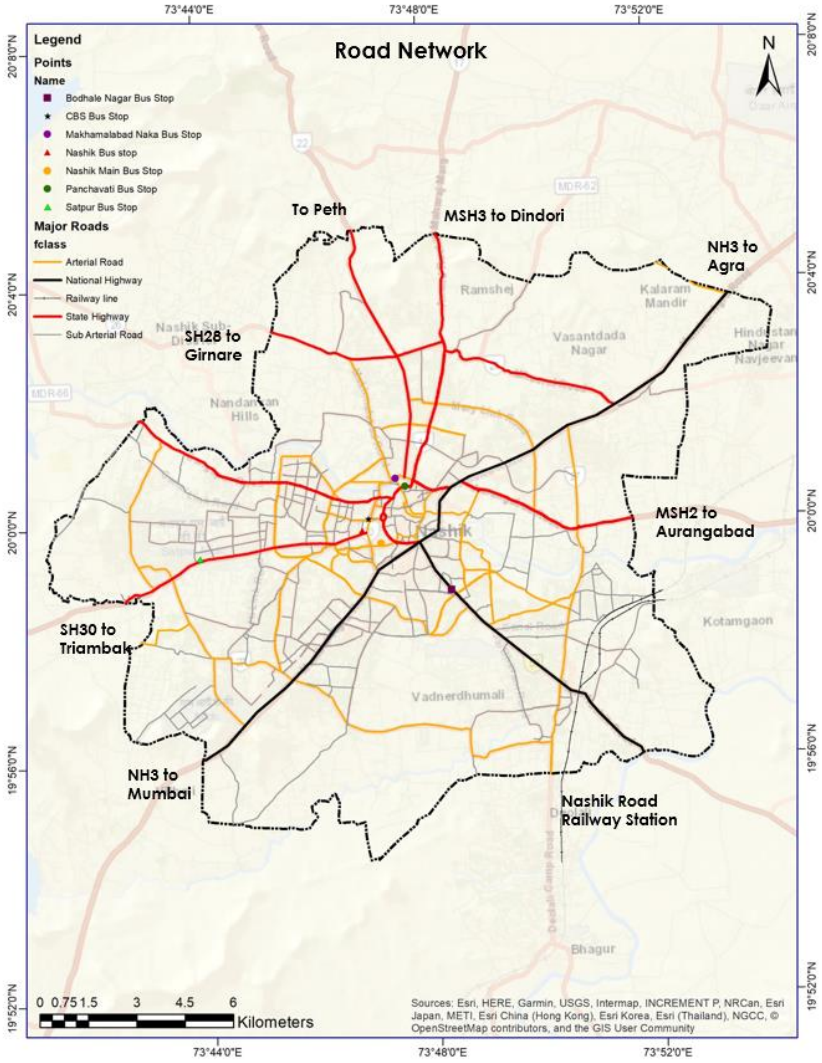


Figure 19- Road Network for Nashik City (Source- CMP)

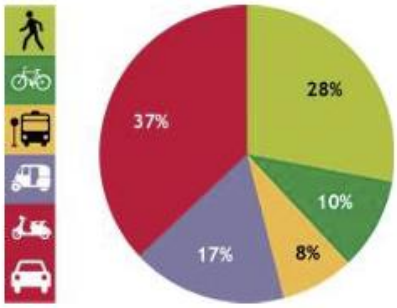


Figure 18-Modal Split for Various Modes(2013) (Source- CMP)

Code	Mode	Avg. Trip Length (km)	Avg. Trip Time (min)	Avg. Waiting Time (min)
1	Walk	0.8	17.5	-
2	Car / Jeep / Van / Taxi	5.7	26.8	-
3	2-Wheeler	5	23.9	-
4	Auto-Rickshaw	4.4	25.3	6.9
5	Shared Auto / Tata Magic	4.2	26.2	8.5
6	City Bus (Govt.)	6	26.8	9.9
8	Private Bus	4.3	23	8.5
9	Mini Bus	4.5	29.6	7.8
10	Cycle	2.7	21.4	-
11	Cycle Rickshaw	1.7	16.4	5

Table 10- Avg Trip length, waiting time and duration for various modes

Nashik's urban zones serve distinct functions based on land use and user groups. Panchavati and Ramkund act as religious and cultural hubs for residents and tourists. College Road and Canada Corner are educational and commercial zones attracting students and shoppers. The Civil Hospital area forms a medical services cluster serving the public and suburban populations. Satpur and Ambad MIDC are key employment and industrial zones for workers and logistics. Nashik Road Railway Station and CBS serve as major transit hubs. Gangapur Road and the Green Belt are residential and recreational spaces for middle-to-upper class residents and fitness users. The Main Market and M.G. Road form the commercial heart of the city, and institutions like KTHM, BYK College, and YCMOU define the academic core. This functional classification highlights Nashik's diverse and user-specific urban landscape.

Table 11- Trips in Kumbh Mela and Normal Days

Category	Normal Days	Kumbh Mela Period
Population in City	~20 lakhs	**80–100 lakhs** (including pilgrims and tourists)
Avg. Trips/Person/Day	1.2–1.6	**1.5–2.0**
Estimated Total Trips/Day	24–32 lakh	**120–180 lakh (12–18 million)**
Modes of Travel	Regular city mix	**Walking (high %), buses, rickshaws, foot bridges**

The Kumbh Mela significantly impacts transportation patterns in Nashik, as increased demand for mobility services and road space creates congestion and inefficiencies. This directly relates to your study on travel behavior and accessibility.

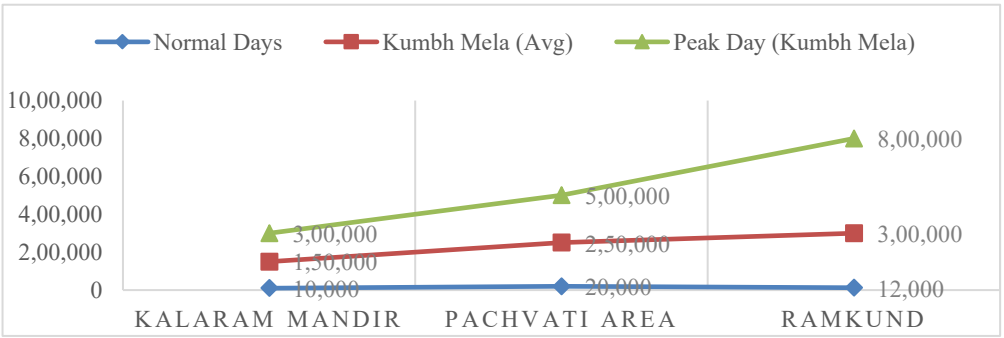


Figure 20- Inflow of Tourist During Normal Times and Kumbh Mela

The modal split data for Nashik from 2013 to the predicted values for 2021 indicates a growing shift toward private motorized transport. Walking has steadily declined from 28% in 2013 to a predicted 12.5% in 2021, reflecting reduced walkability and increased urban sprawl. Two-wheeler usage has risen significantly, from 37% in 2013 to a projected 45.9% in 2021, indicating a growing dependence on affordable personal transport. Similarly, four-wheeler usage increased from 17% to 24% over the same period, likely driven by rising incomes and urban expansion. In contrast, intermediate public transport modes such as auto-rickshaws show minimal growth, remaining around 6%. Public transport share improved from 10% in 2013 to 24% in 2016 but remained stagnant thereafter, highlighting the need for enhanced transit infrastructure.

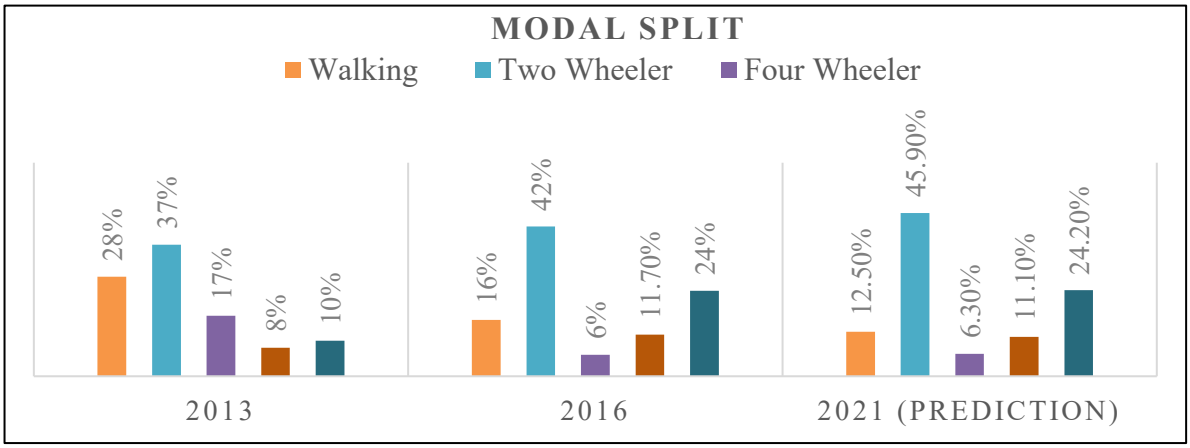


Figure 21- Modal Split of 2013,2016,2021

3.3 Data Collection

This study utilizes data sourced from secondary sources. It included City base map from Nashik Municipal Corporation (NMC), built-up area imagery extracted from USGS Earth explorer, Roads from Open Street maps (OSM), Population density projected from voter data for 2024. bus stops and routes from Citi-Line' website. Hospitals, Education institutes, recreation areas locations from directorate of health services, Nashik school education portal respectively.

3.4 Data Analysis of the selected indicator

Data analysis is further carried through thirteen identified Indicators as discussed in Table 3 Table 4. The analysis of the existing conditions of the study area is discussed below.

3.4.1 Compactness indicator

Population Density

The distribution of population density across Nashik varies considerably, with the central city core and old town areas being highly compact and densely populated. In contrast, peripheral areas and newly developing zones, including parts of Nashik Road, Indira Nagar, and Ambad, show lower density but are rapidly urbanizing.37.5% rise, indicating intensified urbanization and possibly increased pressure on infrastructure, housing, and mobility systems.

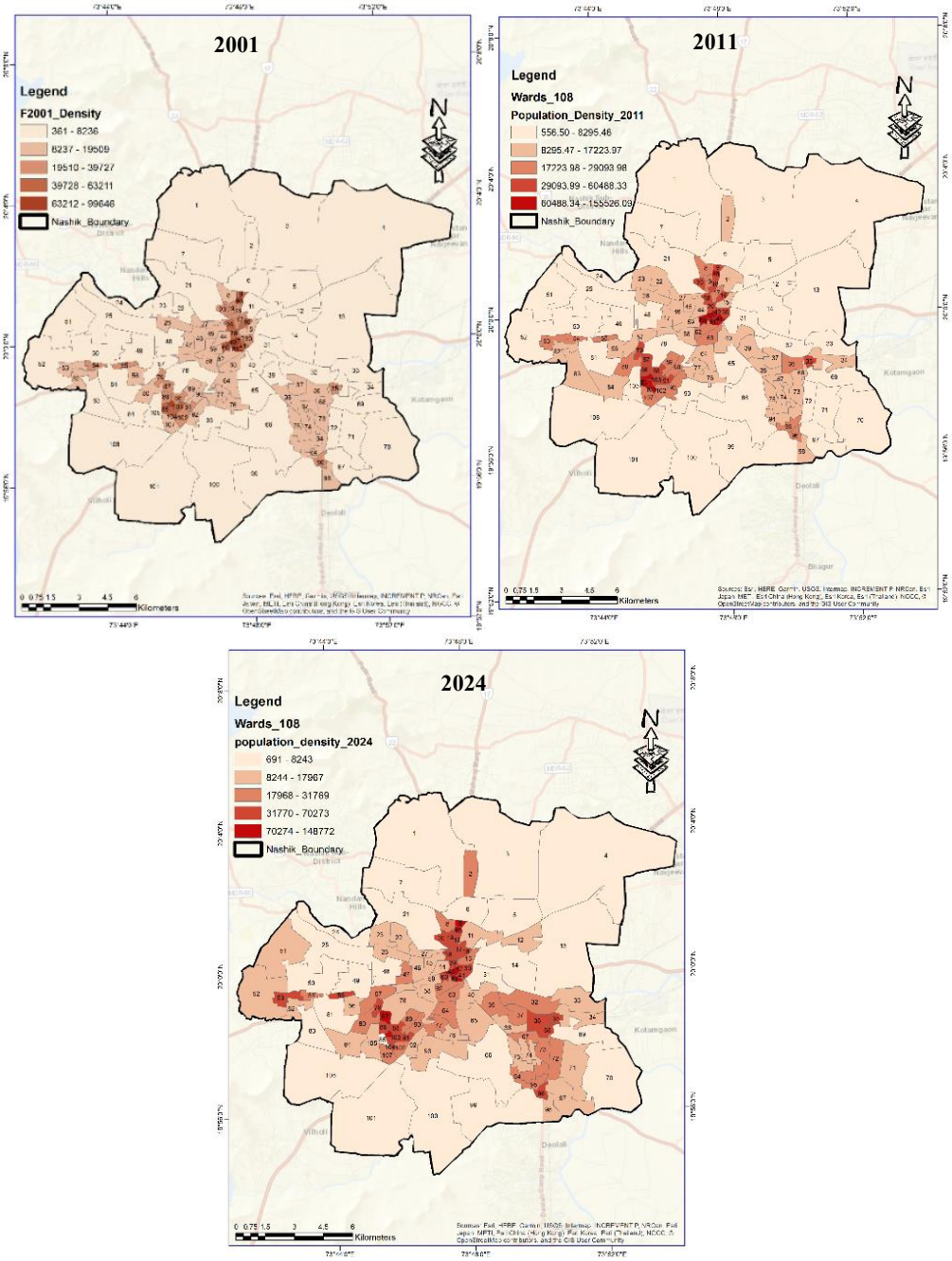


Figure 22- Population Density for 2001,2011,2024

Population as per census 2011 is 1486053.

Population Density= 5566/ sqkm.

Table 12- Change in Population and Population density

	2001	2011	2024
Population	1077236	1486053	2042487
Population Density (Per sqkm)	4035	5566	7650

The graph (Figure 23) shows that wards with shorter trip distances often have higher population densities, particularly in central and mixed-use zones. Conversely, longer trip distances are more common in low-density peripheral wards, indicating a spatial disconnect between housing and daily activity centers (jobs, schools, transit).

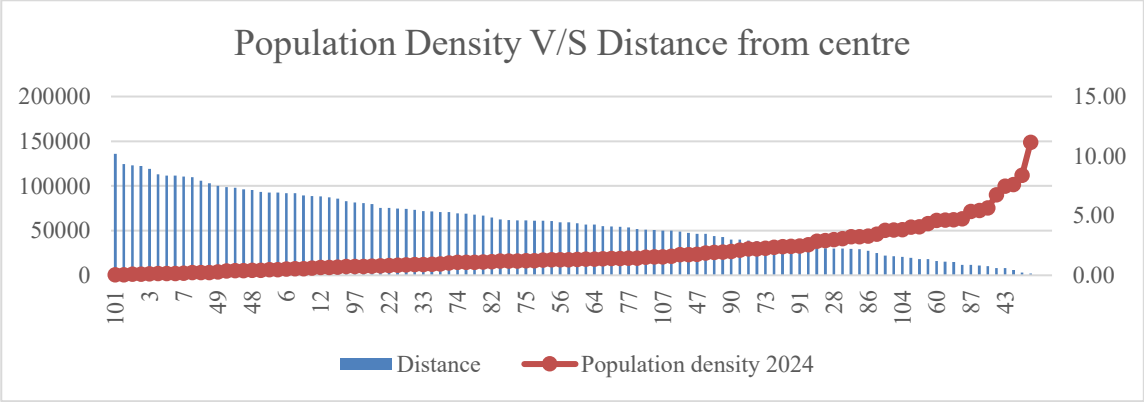


Figure 23- Population Density V/s Distance from Centre (Source- Author)

Built up Density

Built-Up Density= Total Built-Up Area /Total Land Area in the Zone

=114.2/ 267 = **0.42**

Moderate built-up growth, ideally ranging between 50–60%, indicates a controlled and balanced urban expansion. This level of growth suggests that the city is not experiencing excessive sprawl and offers an opportunity to implement sustainable strategies such as infill development, redevelopment, and densification of underutilized areas.

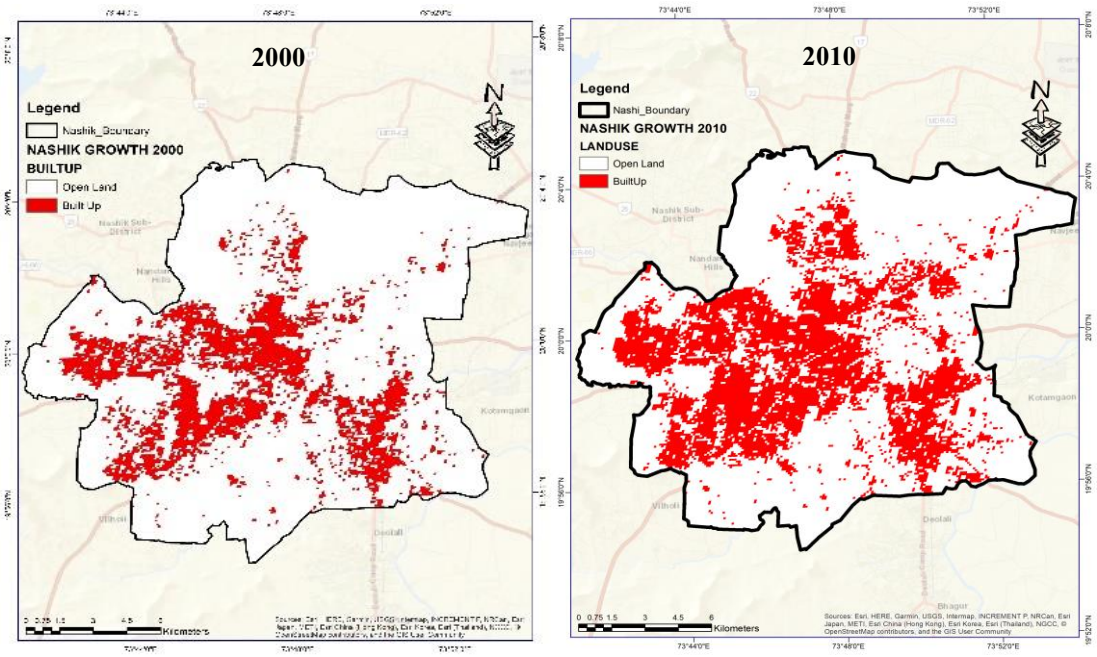


Figure 24- Built-up Density for 2000, 2010

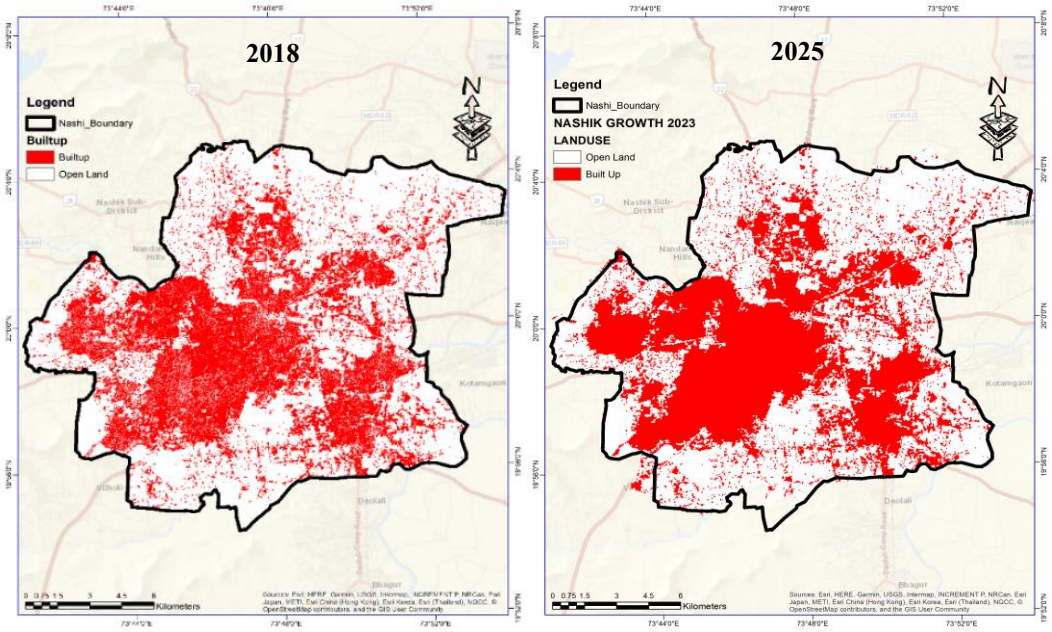


Figure 25-Built-up Density for 2018,2025

Nashik's urban form features a dense core, emerging polycentric nodes, linear growth along transport corridors, and fragmented sprawl at the urban fringe(See in Figure 28).

A concentrated core of dense built-up area is evident in the central part of the city, signifying the historical and primary zone of development. Extending outwards from this core, the growth transitions into a sprawling periphery characterized by a more dispersed and less dense

built environment. Furthermore, linear development patterns are noticeable, particularly along major transportation corridors radiating from the center, indicating growth influenced by connectivity.

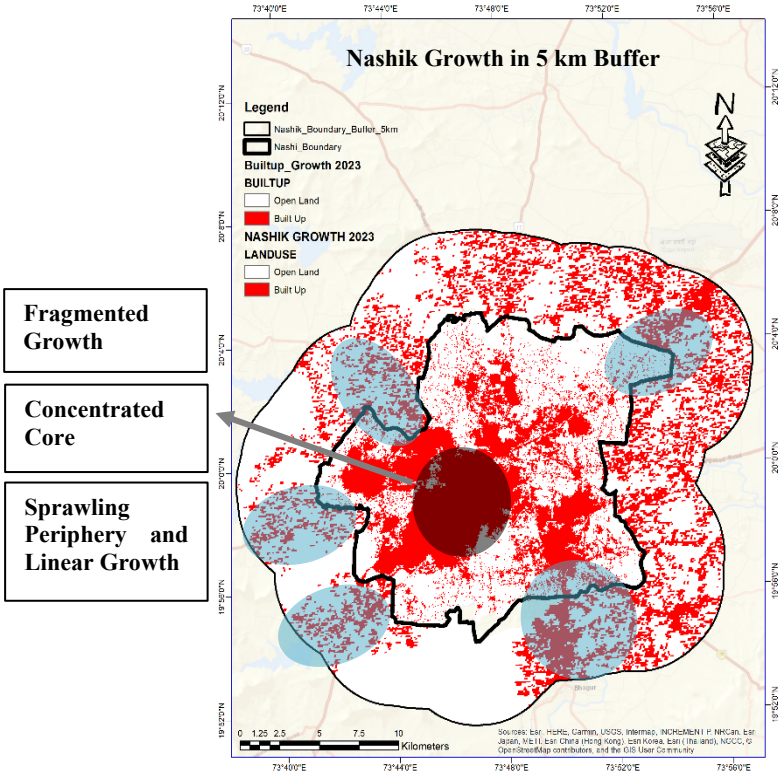


Figure 28- Growth in 5km buffer around the boundary

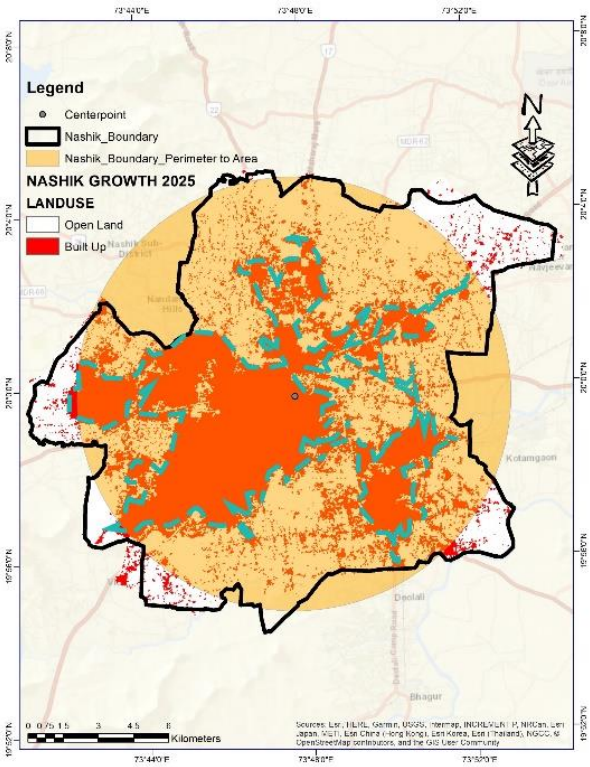


Figure 27- Perimeter to Area Ratio

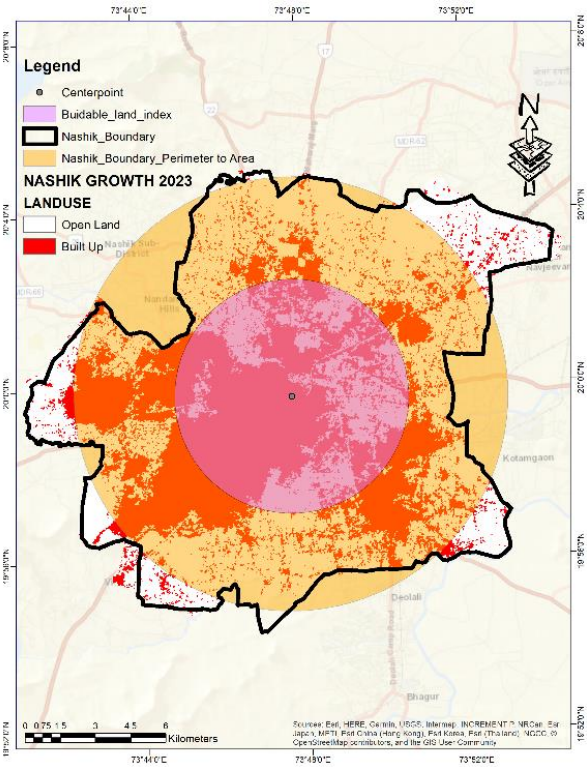


Figure 26- Buildable Land Index

Perimeter to Area Ratio

Perimeter to Area Ratio= Perimeter / Area

= 115/267 sq km

=0.43

In Nashik's case (Refer Figure 27), the moderate value suggests that the city is neither overly compact nor excessively spread out, but is in a transitional phase. It highlights a balance between densified development in the central areas and expansion in the outer zones, which if left unregulated, could lead to inefficient land use and increased dependency on private transport.

Buildable Land Index

Moderate value suggests constraints in the central area**.** Balanced potential for future development while still retaining ecological and spatial constraints (Refer Figure 26).

North, West, and South-East fringes offer high potential for infill and buildable expansion.

Buildable Land Index= **0.45**

Saturation and Porosity Index

Saturation=**51.6% (0.51)**

Porosity Index= **52.4 % (0.52)**

The moderate saturation and porosity values observed in Nashik's urban structure—ideally ranging between 0.6–0.7 for saturation and 0.25–0.35 for porosity—indicate the presence of underutilized and fragmented development, particularly in the peripheral zones (Refer 29). These values suggest that while the built environment has begun to take shape, there remains significant scope for densification and spatial consolidation in the outer areas of the city. This fragmented pattern often results in large vacant plots, uneven building distribution, and disconnected urban patches, leading to inefficient land use and increased distances between residential, commercial, and institutional functions. Consequently, residents in these areas tend to rely more heavily on private vehicles, contributing to congestion, environmental degradation, and unequal access to urban amenities.

Contiguity and Dispersion Index

Contiguity Index-**0.41** (Refer Figure 30)

Table 13- Dispersion Index for the year 2001,2011,2024

	2001	2011	2024
Dispersion Index	1.52	1.55	1.50

Nashik's urban form presents a mix of consolidated built-up areas interspersed with disconnected and fragmented development, particularly noticeable along the urban-rural fringe(See Figure 29). This pattern is especially evident toward the north, northeast, and southeast edges, where built-up continuity is interrupted by vacant land, agricultural plots, and unplanned growth. Such spatial breaks reflect low contiguity and higher dispersion, with ideal benchmark values being contiguity >0.75 and dispersion between 1.2–1.5.

This results in inefficient infrastructure provision, increased costs for urban services, and weak integration between developed and undeveloped zones. Additionally, it often leads to car-dependent lifestyles, reduced accessibility, and ecological fragmentation due to uncoordinated expansion.

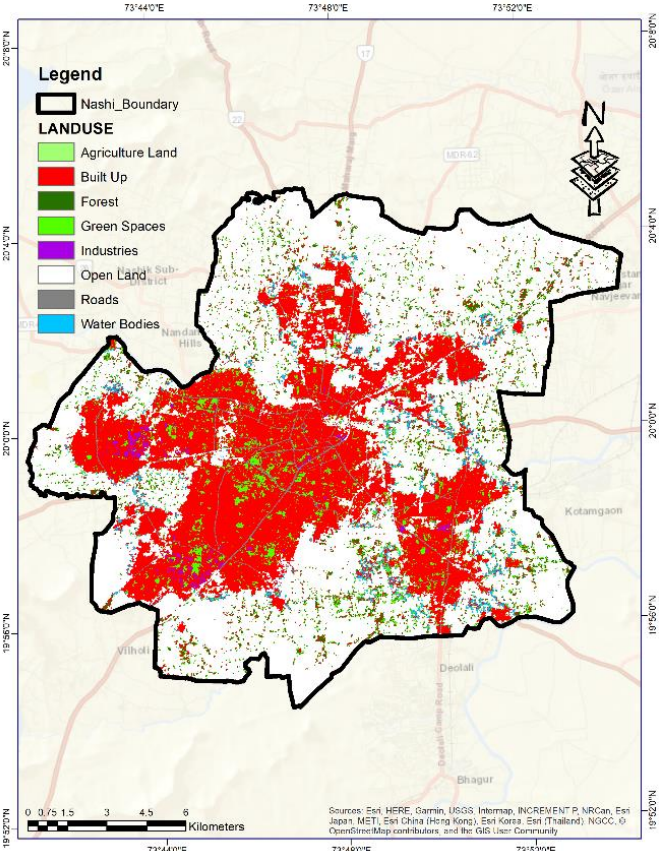


Figure 30- Saturation and Porosity Index

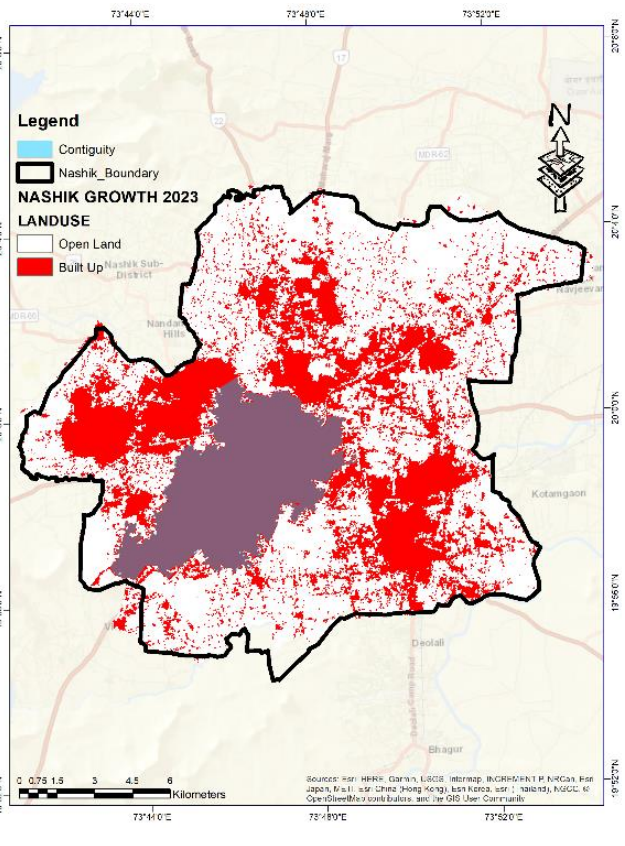


Figure 29- Contiguity and Dispersion Index

3.4.2 Travel Indicators

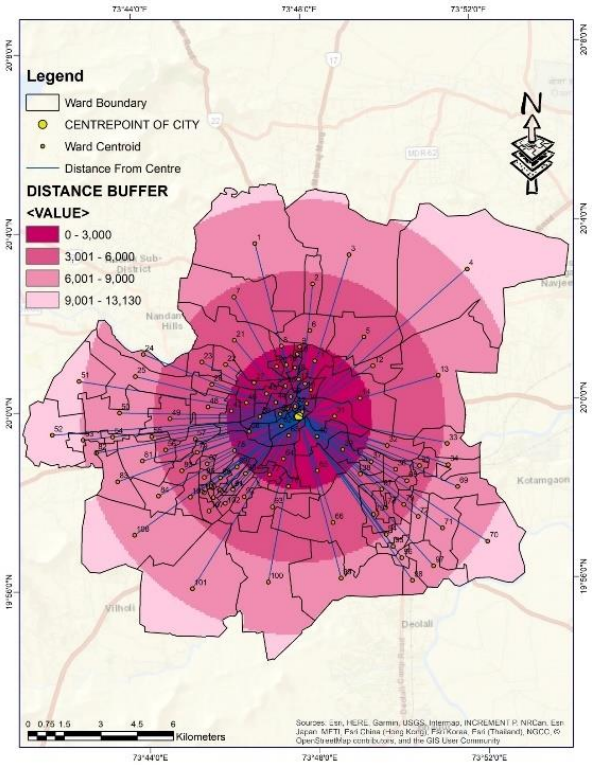


Figure 32- Average Travel Distance Per Person

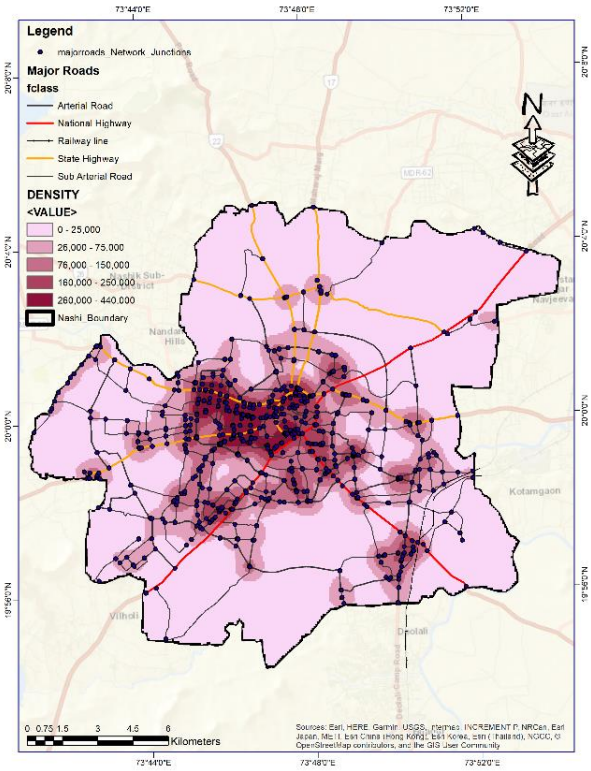


Figure 31-Link Node Ratio

Average Travel Distance Per Person

Table 14- Avg Travel Distance for 2000,2011,2024

	2001	2011	2024
Avg Travel Distance per person	4.46	4.80	4.95

In an ideal urban environment, the average travel distance per person should be less than 3 km, promoting walkability and the use of public transport(Refer -Figure 32). However, the spatial spread and fragmentation in Nashik indicate that trip lengths exceed the ideal threshold, with many residents in peripheral areas needing to travel longer distances for work, education, and other daily activities. This results in increased reliance on private vehicles, contributing to traffic congestion, longer commute times, and reduced sustainability in the urban transport system.

Link Node Ratio

Nodes – 2017

Links- 2400 =Link Node Ratio- 2400/2017 = **1.18** (Refer-Figure 31)

This ratio indicates a relatively low to moderate level of network connectivity in the city. the ratio reflects limited route options and potential inefficiencies in circulation. A key concern is Mumbai Naka, a major convergence point for arterial roads, which functions as a critical node but frequently experiences congestion due to high traffic volumes—particularly during peak hours. This bottleneck affects overall mobility and underscores the need for improved intersection management and network optimization.

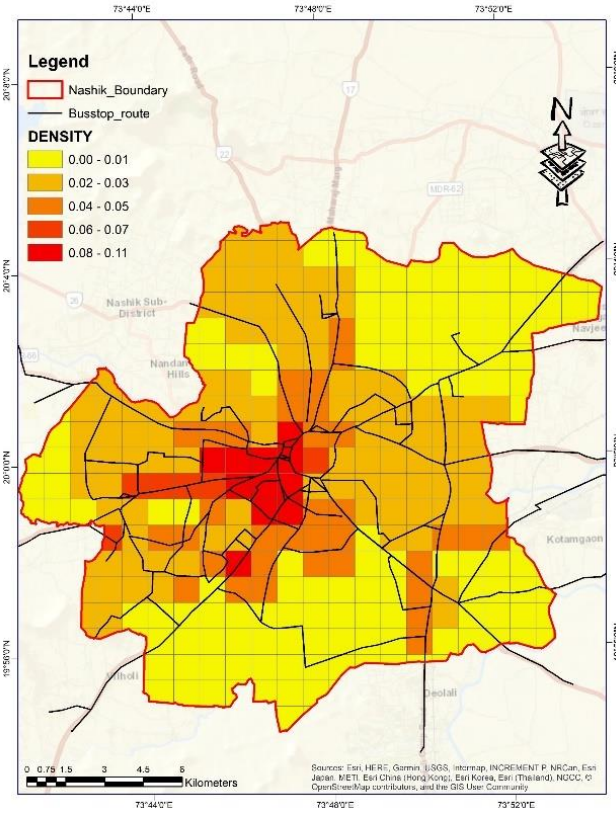


Figure 34- Road Density Map

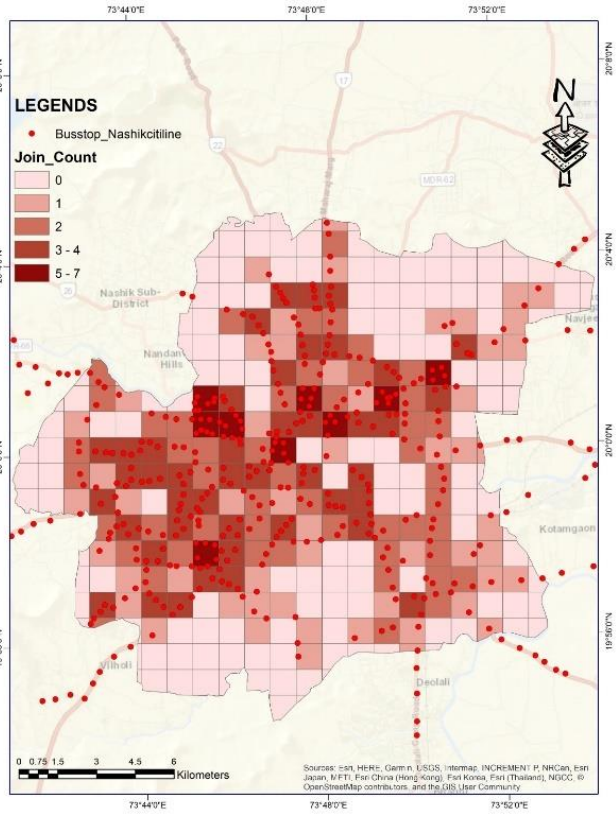


Figure 33-Public Transit Density Map

Road Density

Average Road Density =Total Road Length/ Total Area

=491/267 =**1.83** (Refer - Figure 34)

With an average road density of 1.83 km/sq.km (491 km of total road length over 267 sq.km area), Nashik exhibits relatively low infrastructure coverage, particularly in its peripheral zones. This limited road network in outer areas restricts accessibility to key urban centres and services, often resulting in longer travel times and higher dependence on private vehicles. Such conditions can exacerbate traffic congestion and contribute to increased emissions, underscoring the need for targeted road infrastructure development in suburban and expanding

urban areas.

Public Transit Density

Nashik's public transit system comprises 233 buses and 1,392 bus stops, averaging 2–3 stops per square kilometer(Refer -Figure 33). While this density adequately serves the city's central areas, the peripheral zones face limited coverage, with fewer or no direct bus services. This spatial disparity compels suburban residents to depend on private vehicles or undertake longer commutes to access transit hubs. The uneven distribution highlights the need to expand service reach and improve stop density in outer areas to promote equitable access and reduce pressure on central road networks.

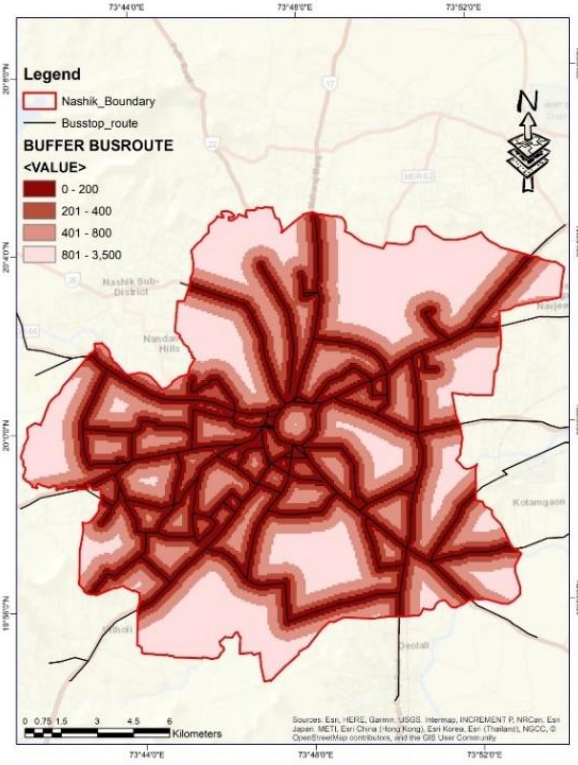


Figure 36- Public Transit Coverage

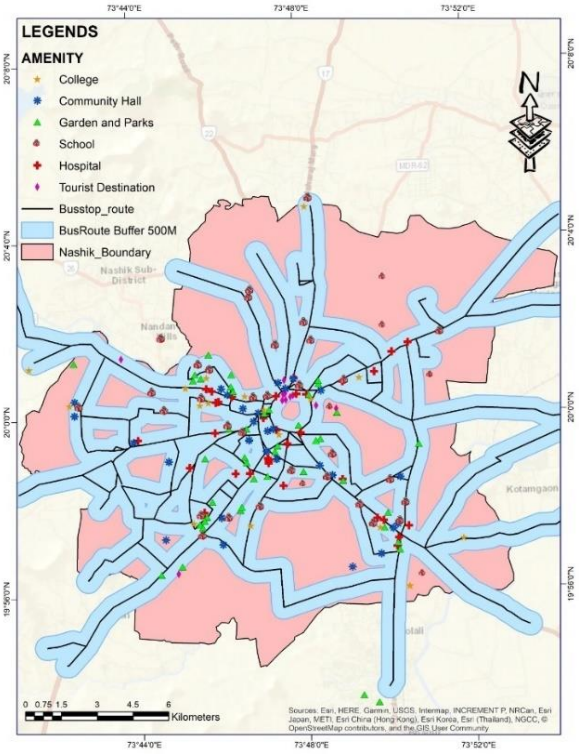


Figure 35- Proximity Index of Public transit

Public Transit Coverage

Public transit coverage is concentrated in the central zones, while approximately 55% of peripheral areas remain under-served(Refer - Figure 36). This imbalance compels a significant portion of outer-city residents to depend on private vehicles, leading to longer commutes, congestion, and inefficient land use. The inadequate coverage in fringe zones underscores the urgent need to expand bus routes and increase service frequency to ensure equitable

accessibility, reduce traffic pressure, and support sustainable urban mobility across the city.

Proximity Index

The central core of Nashik has a higher concentration of amenities—such as healthcare, education, markets, and transport—compared to the peripheral areas, leading to a spatial disparity in service access. This uneven distribution means that residents in the outer parts of the city must travel longer distances to access basic facilities, increasing daily travel burdens and dependence on private vehicles. Nearly 55% of the peripheral zones are underserved, highlighting a need for more decentralized planning (Refer -Figure 35).

These indicators provide critical insights into the factors shaping urban form and influencing travel behavior, enabling more informed and effective planning decisions.

Chapter 4-
Inferences and Gap Analysis

4.1 Inferences

Population Density and Travel Distance

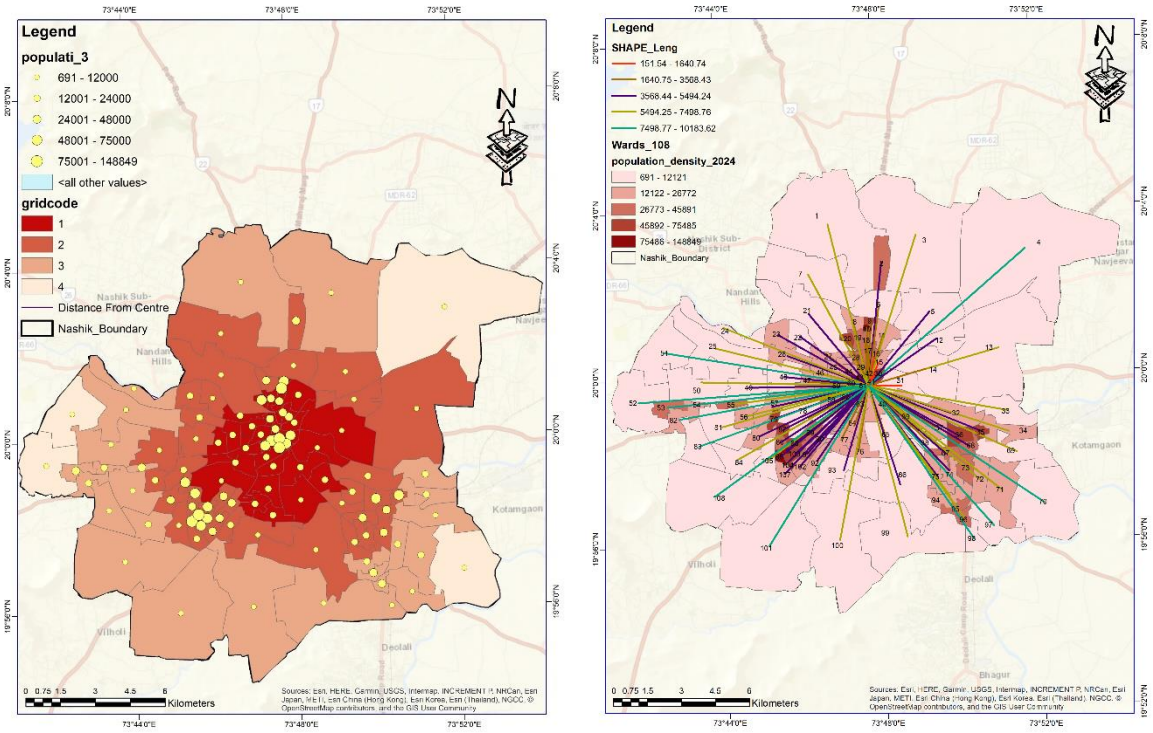


Figure 37- Population Density and Travel Distance Map

Nashik's urban structure exhibits a radial decline in population density, with the central core recording densities above 10,000 persons/km², while peripheral zones fall below 4,000 persons/km² (Refer -Figure 37). This disparity has led to spatial imbalance, where central areas benefit from better infrastructure, services, and public transport access, resulting in shorter travel distances and efficient mobility. Conversely, the outer urban belt and peripheral zones remain underdeveloped, with limited accessibility and fragmented land use, driving higher reliance on private vehicles and longer trip lengths. As per Table 17, development intensity diminishes progressively from the central core to the periphery. This over-centralization and lack of compact growth underscore the need for Transit-Oriented Development (TOD), strategic infill in low-density zones, and improved connectivity to enable balanced, sustainable urban expansion.

Table 15- Area and its relation with development

Areas (Core)	Urban Development Status
1 (Central Core)	Highly Dense, Major Activity Centers
2 (Intermediate Zone)	Moderately Developed, Growth Potential
3 (Outer Urban Belt)	Emerging Development, Infrastructure Expansion Needed
4 (Peripheral Zone)	Low Density, Limited Urban Accessibility

Population Density and Accessibility

Population density and public transport accessibility are closely linked, shaping mobility patterns and urban efficiency. High-density areas, accommodating populations between 60,001 and 155,526 people/km², enjoy 80% bus stop coverage, while medium-density zones (10,001–30,000 people/km²) have 60% coverage. In contrast, low-density areas (556–10,000 people/km²) receive only 35% coverage, underscoring a clear accessibility gap(Refer-Figure 38). Approximately 60% of residents in medium- to high-density zones are within accessible transit ranges; however, several densely populated wards—such as 56, 81, and 96—fall outside the 500-meter buffer of bus stops, revealing critical deficiencies. Peripheral wards are even more underserved, with minimal connectivity and limited public transport options. Overlapping routes in central areas contribute to congestion, while the absence of feeder systems hinders last-mile connectivity.

Table 16- Relation between Population density and Bus stop coverage

Category	Population Density (people/km²)	Bus Stop Coverage (%)
High Density	60,001–155,526	80%
Medium Density	10,001–30,000	60%
Low Density	556–10,000	35%

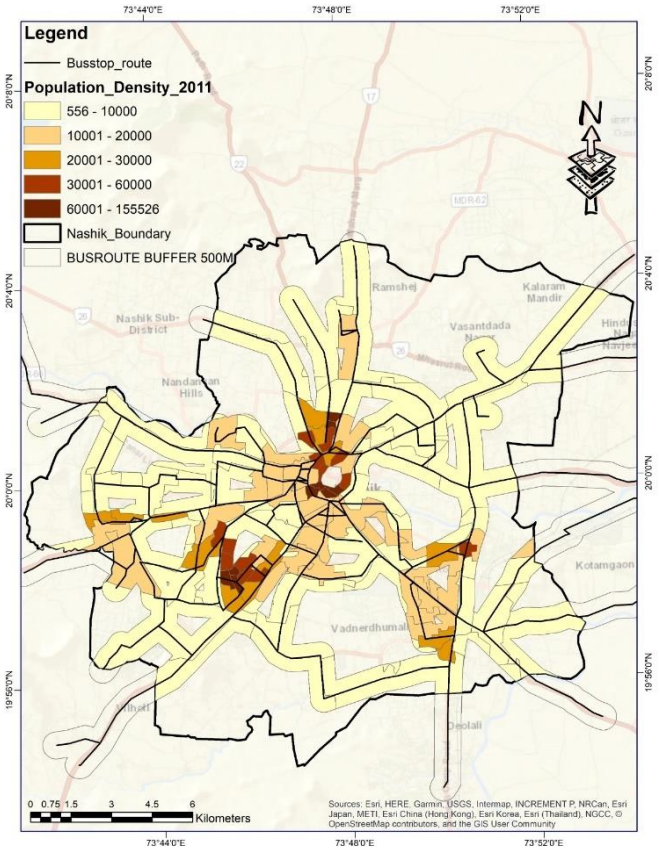


Figure 38- Population Density in Transit Corridor

4.2 Gap Analysis

The gap is identified based on the benchmarking of the indicators and calculate the overall composite score.

Table 17-Compactness Indicator and its rating

Indicator	Ideal Range	Inferences	Value	Score
Population Density (Gross)	>100 pph	Highly uneven population density with a clear concentration in the central areas and a gradual decrease towards the outskirts	77	3
Built-up Density	60-40%	Increasing sprawl, potential polycentric tendencies, linear development along transport routes, and a fragmented growth pattern in the periphery	0.42	3
Saturation	60-70%	Scope of controlled growth and balanced densification especially in peripheral zones.	51.6	3
Land-Use (% of Road)	12-15%	The city could have more strong and equally distributed land use.	6%	3
Porosity Index	15-25%	Need a balanced growth to protect open spaces with urban expansion.	52.4	2
Shape Index	12-15(Lower the better)	Moderate value indicates from is less compact with more travel distance.	0.43	3
Contiguity Index	>0.75	A mix of consolidated built-up areas and disconnected patches, especially at the urban-rural fringe.	0.41	2
Buildable Land Index	>0.80	A low buildable land index in the core signals the need for strategic land use and infrastructure planning to support sustainable population growth.	0.45	2
Dispersion Index	<1.2-1.5	Mix of consolidated cores and fragmented, disconnected patches, particularly along the urban-rural fringe.	1.50	3

Table 18- Travel Behavior Indicators and its rating

Indicator	Ideal Range	Inferences	Value	Score
Avg Trip Length Per Person	<3 sqkm	Highly uneven population density with a clear concentration in the central areas and a gradual decrease towards the outskirts	4.95 sqkm	3
Modal Split (PT Share)	>40%	Increasing sprawl, potential polycentric tendencies, linear development along transport routes, and a fragmented growth pattern in the periphery	11.70%	2
Link Node Ratio	>2.5	Scope of controlled growth and balanced densification especially in peripheral zones.	1.08	2
Road Density	>3 km	There are incomplete routes and lack of roads in the periphery which affects the accessibility.	1.83	3
Transit Density	>5 per sqkm	Need a balanced growth to protect open spaces with urban expansion.	2-3 stops per sqkm	2
Public Transit Coverage	80-65%	Moderate value indicates still a score to cover the periphery are to increase the coverage.	56.17%	3

Proximity Index of PT (within 500m)	>80%	Moderate value indicates from is less compact with more travel distance.	56%	3

This Table17 and Table 18 compares Nashik's urban form and travel behaviour indicators against ideal benchmarks. Under Compactness, indicators like Population and Built-up Density, Saturation, Shape, Porosity, and Contiguity consistently score 3, reflecting moderate compactness with central concentration, peripheral fragmentation, and scope for densification. The Buildable Land and Dispersion indices also suggest limited core availability and moderate sprawl.

In Travel Behaviour, the Average Trip Length of 4.95 km scores 4, indicating moderately long commutes. However, heavy dependence on private vehicles (87%) scores just 1, and infrastructure indicators such as Link-Node Ratio (1.18), Road Density (1.83 km/sq km), Transit Density (2–3 stops/sq km), and Transit Proximity (55%) all score low (1–2), pointing to weak public transport access and poor connectivity. Overall, while urban compactness is moderate, mobility patterns underscore the urgent need for improved transit infrastructure and reduced car reliance.

4.2.1 Composite Index for the Study Area

Composite Index for the Nashik city is calculated using the geometric aggregation and found to be 2.51 out of 5 which fall in poor to moderate range of scoring as shown below.

$$\text{Composite Score} = \sqrt[n]{(\text{Product of Scores of All Indicators})}$$

Where n is the number of indicators

$$= \textbf{2.51 out of 5} \text{ (Poor – Moderate).}$$

4.2.2 Spatial Gap Identification

Spatial analysis of compactness and travel behavior indicators in Nashik reveals critical urban gaps that hinder sustainable development. Compactness metrics—such as population density (ranging from 556 to 155,526 people/km²), built-up density (0.42), and land-use contiguity—highlight fragmentation in peripheral and transition zones, where spatial dispersion reduces development efficiency. Travel behavior indicators further expose inefficiencies: the average trip length ranges from 4.3 to 5.7 km, while public transport share remains moderate (around 20%), with walkability and last-mile connectivity lacking in several areas. Road density is

1.83 km/sq.km, and link-node ratio stands at 1.18, indicating moderate connectivity. These insights underline the need for targeted land-use policies, enhanced transit infrastructure, and compact development strategies to foster equitable access and improve overall urban mobility.

Indicators

Population density and Buildable land Index

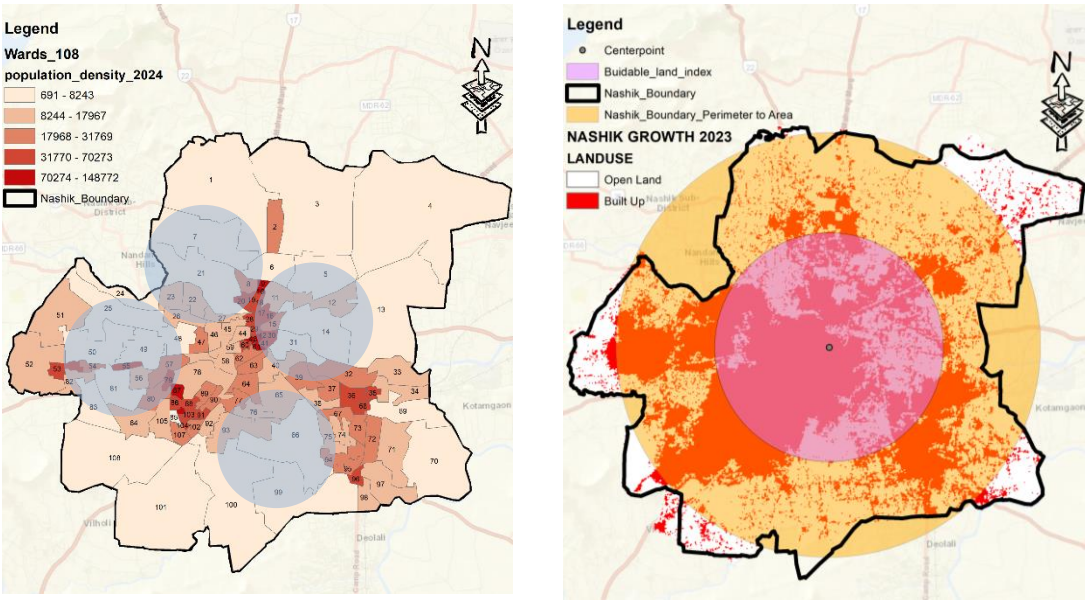


Figure 39- Issues identified for Population Density and Buildable Land Index

Population density in Nashik is concentrated in the core, straining central infrastructure, while peripheral areas remain underutilized. The Buildable Land Index reveals fragmented land availability in fringe zones, constrained by irregular plots and regulatory barriers.

PossibleInterventions

I. Encourage infill and vertical development in low-density, infrastructure-ready areas.

II. Implement land aggregation strategies and zoning reforms to enhance buildable land supply.

III. Integrate density planning with transit corridors to promote compact, balanced urban growth.

Perimeter to Area Ratio

A higher Shape Index, as observed in Nashik (0.41), reflects an elongated and irregular urban footprint, often stemming from uncoordinated expansion along major transit routes and natural constraints. This pattern results in fragmented development, inefficient land

utilization, and elevated infrastructure costs, particularly in peripheral zones. The spatial discontinuity undermines accessibility and diminishes the viability of public transport and walkable environments, detracting from the principles of compact urban growth.

Possible Intervention

I. Promote infill development in low-density, serviced areas—particularly in underutilized urban pockets—to improve land efficiency and reduce pressure on peripheral expansion.
II. Encourage vertical growth by reforming Floor Space Index (FSI) norms and providing development incentives to accommodate density without horizontal sprawl.
III. Implement urban growth boundaries and adopt land pooling mechanisms to consolidate fragmented parcels and guide integrated, spatially balanced development.

Saturation and Porosity

A moderate Saturation Index points to underutilized land parcels, while a high Porosity Index indicates fragmented and less compact urban growth. These gaps hinder spatial efficiency and disrupt connectivity within the built environment.

Possible Intervention

I. Promote green space integration within underutilized areas to enhance livability and fill urban voids. Focus on connecting fragmented developments through planned infill, mixed-use zoning, and improved infrastructure to foster a more cohesive and compact

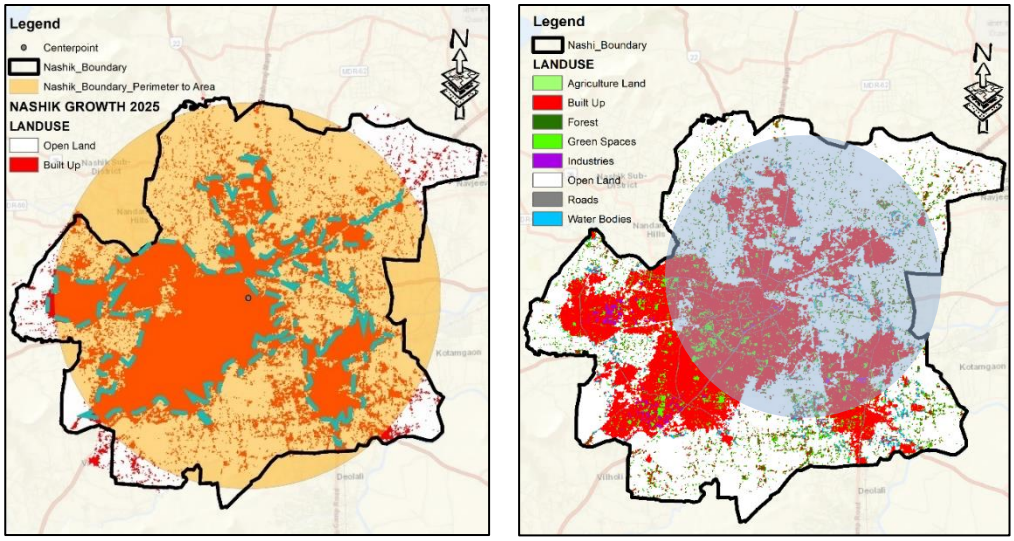


Figure 40- Issues related to Perimeter Area Ratio, Saturation and Porosity

urban form.

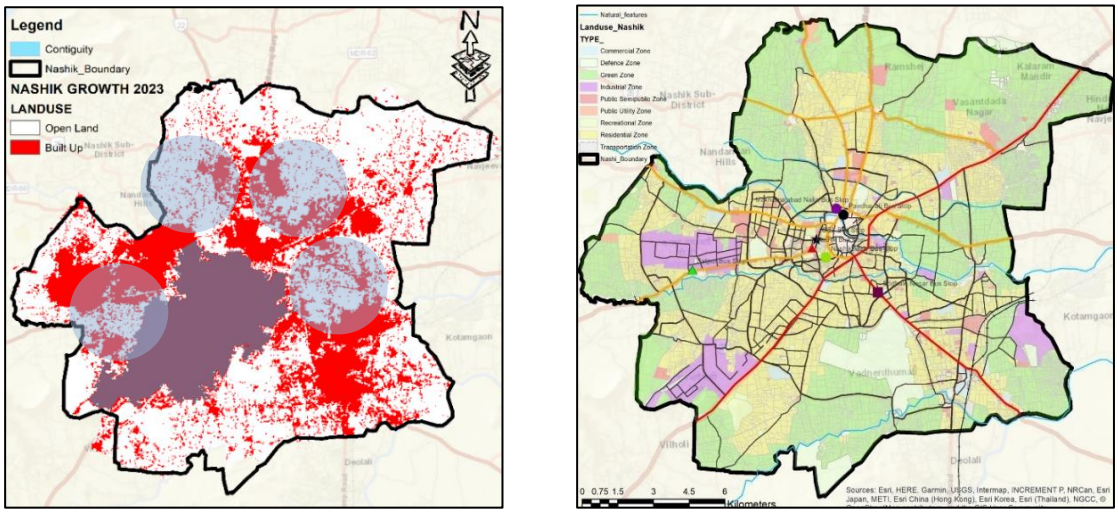


Figure 41-Issues related to Contiguity, Dispersion and Land use map

Contiguity and Dispersion Index

The spatial analysis of Nashik reveals a low Contiguity Index, with discontinuous urban patches, particularly in peripheral zones. Simultaneously, a high Dispersion Index indicates a scattered development pattern, weakening spatial cohesion and increasing infrastructure costs.

Possible Intervention

I. Promote planned infill development to bridge disconnected urban pockets.

II. Implement clustered zoning and align infrastructure investment with growth nodes to enhance contiguity and reduce sprawl.

Land use and Transportation

There is a lack of growth concentration near transit corridors and an uneven distribution of amenities, leading to inefficient land use and limited access to sustainable transport. This spatial mismatch undermines the potential of transit infrastructure and increases reliance on private vehicles.

Possible Intervention

I. Strengthen Transit-Oriented Development (TOD) to channel growth along major corridors.

II. Promote mixed-use zoning to integrate housing, jobs, and services within walkable catchments of transit nodes. This will improve accessibility, reduce travel distances,

and support a compact, efficient urban form.

Average Travel Distance Per Person

The increasing average travel distance in Nashik—rising from 4.3 km (including walk) to 5.7 km (excluding walk)—reflects sprawling growth and spatial misalignment between residential zones and employment or service centers. This pattern leads to longer commutes, higher transport costs, and growing reliance on private vehicles, which currently account for 41.1% of the modal share.

Possible Intervention

I. Promote densification in peripheral areas through infrastructure-led planning.

II. Incentivize redevelopment in low-utilization inner-city wards to balance population distribution.

III. Implement Transit-Oriented Development (TOD) strategies along high-capacity corridors to integrate housing, jobs, and services—thereby reducing trip lengths and fostering sustainable, compact urban mobility.

Link Node Ratio

Nashik's link-node ratio of 1.18 reflects limited road connectivity, particularly in peripheral zones, and congestion hotspots like Mumbai Naka, where multiple arterial roads converge. This imbalance impedes efficient intra-city movement and restricts accessibility, especially during peak hours and festive periods.

Possible Intervention

I. Expand and upgrade the road network in low-density areas to improve connectivity and reduce dependency on central corridors.

II. Promote multi-modal integration—including bus, IPT, and non-motorized modes—to optimize network usage, alleviate core congestion, and enhance urban mobility.

Road Density

Low road density in Nashik's peripheral areas indicates inadequate connectivity and limited network coverage, resulting in poor accessibility and continued dependency on the urban core for services and employment.

Possible Intervention

I. Promote decentralized development by strengthening road infrastructure in low-density zones, introduce new connectors to improve network continuity, and integrate multi-modal transport options to enhance last-mile connectivity and reduce congestion in the core.

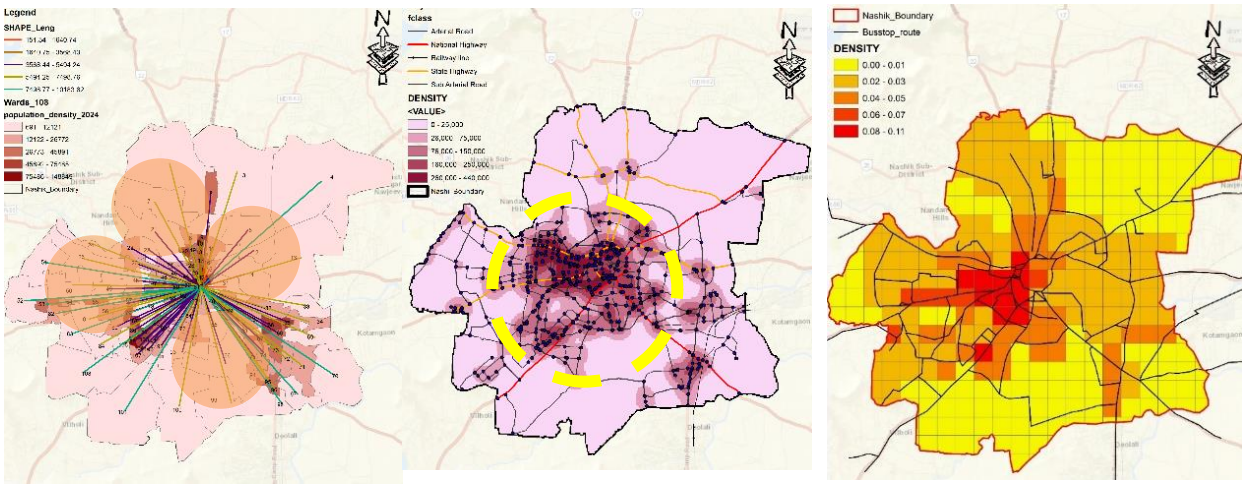


Figure 42- Issues for Average Trip Length, Link Node and Road Density.

Public Transit Density

Nashik exhibits low bus stop density in peripheral and low-density zones, with an average of 2–3 stops per sq.km, and nearly 55% of outer areas lacking adequate public transit access. This limits last-mile connectivity and hampers overall transit efficiency.

Possible Intervention

I. Strengthen the feeder and e-rickshaw networks in underserved zones to bridge the first- and last-mile gaps.

II. Expand bus stop coverage and realign routes to enhance accessibility in low-service areas and encourage a modal shift toward public transport.

Public Transit Coverage

In Nashik, significant coverage gaps on the outskirts and an overreliance on main corridors leave fringe communities underserved by public transit. This uneven network restricts access to jobs and services and reinforces car dependency.

Possible Intervention

I. Expand bus routes into peripheral wards to close coverage gaps, and bolster last-mile connectivity—via micro-shuttles, cycle lanes, or walkable pathways—to integrate

these areas fully into the city's transit system.

Proximity Index

The low Proximity Index in Nashik's peripheral areas indicates a lack of access to essential amenities such as schools, healthcare, and markets. This spatial gap forces residents to rely on distant urban cores, increasing travel demand and reducing quality of life.

Possible Intervention

I. Promote TOD-based development to cluster housing, transit, and amenities within walkable distances.

II. Prioritize amenity creation in peripheral zones to ensure equitable access and support balanced, compact urban growth.

These helps in analysis of the city and identification of the gaps for proposals.

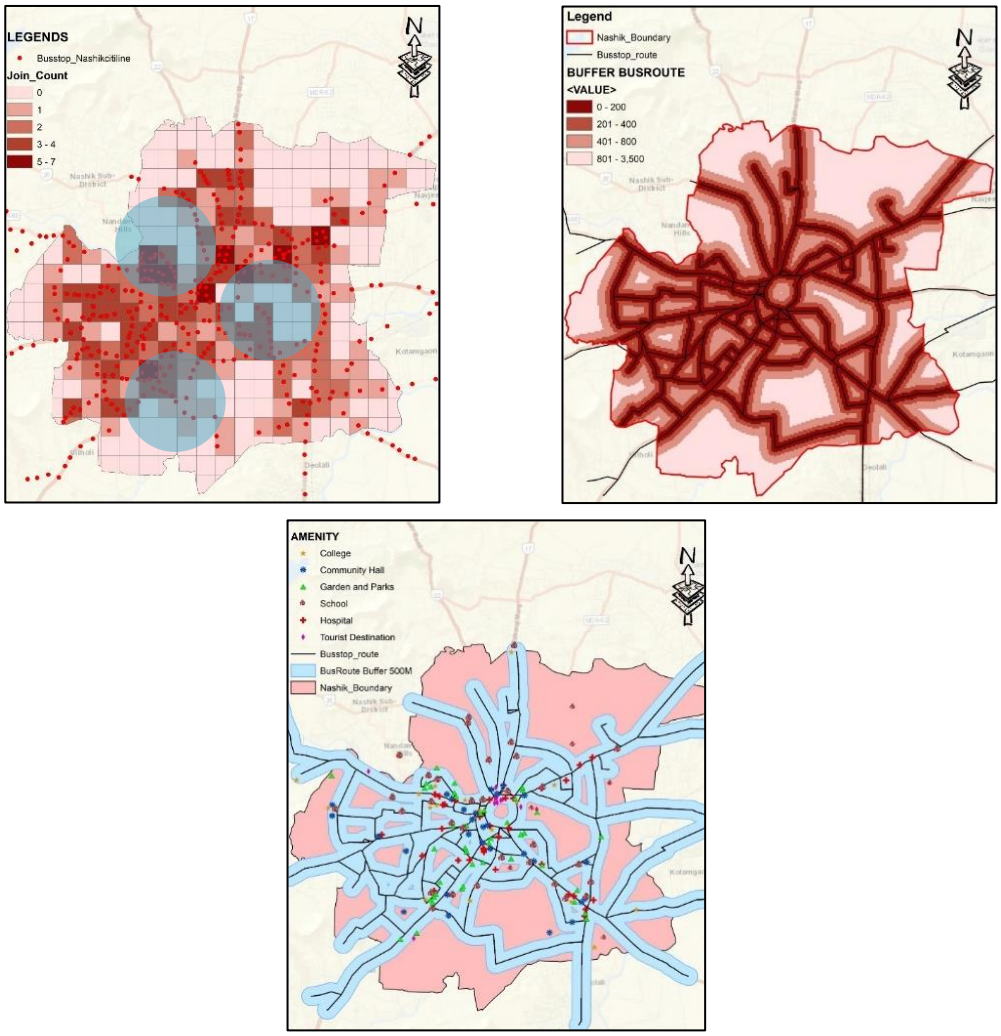


Figure 43 - Issues highlighted for Public Transit Density, Coverage and Proximity

Table 19- Gap Identification through the indicators

Indicator	Identified Gaps	Recommendations
Population Density	Uneven distribution; dense core and sparse periphery	Promote infill and vertical growth; incentivize development in underused areas
Buildable Land Index	Fragmented parcels and constrained usable land	Enable land pooling; reform zoning to unlock buildable plots
Saturation Index	Underutilized land parcels, especially in transition zones	Adaptive reuse of vacant plots; encourage compact zoning
Porosity Index	Fragmented growth; poor spatial cohesion	Integrate green spaces; connect gaps via planned infill
Shape Index	Tentacle-like, unstructured growth along corridors	Control sprawl; support nodal development and vertical growth
Contiguity Index	Discontinuous urban patches	Plan clustered development; improve spatial continuity
Dispersion Index	Scattered and uncoordinated urban form	Guide growth through zoning; focus on growth nodes
Land Use & Transport	Lack of TOD near transit; uneven amenity spread	Implement TOD; support mixed-use zoning
Travel Distance/Person	Increased distances due to sprawl	Densify periphery; reduce core dependency; promote TOD
Link-Node Ratio	Weak road connectivity in outer areas; core congestion	Improve roads in low-density areas; support multi-modal networks
Road Density	Sparse road coverage on city fringes	Develop new roads and connectors; decentralize traffic loads
Public Transit Density	Low bus stop density; route imbalance	Expand feeder networks; improve transit access in low-density zones
Public Transit Coverage	Gaps in outer zones; overreliance on main corridors	Extend coverage to periphery; strengthen last-mile solutions
Proximity Index	Lack of amenities in fringe areas	Develop peripheral amenities; integrate land use with TOD

The analysis of urban indicators reveals several spatial and infrastructural gaps in Nashik's development. Key issues include uneven population density, underutilized land, fragmented growth, poor connectivity, and limited public transit access—particularly in peripheral areas. These challenges result in increased travel distances and inefficient land use. To address these, the study recommends targeted strategies such as promoting infill and vertical development, enabling land pooling, implementing Transit-Oriented Development (TOD), enhancing road and public transport networks, and integrating amenities in outer zones. These measures aim to create a more compact, connected, and accessible urban form that supports sustainable growth and improved travel behavior.

Chapter - 5
Proposals For Nashik City

5.1 Policy

To promote compact, sustainable, and accessible urban growth in Nashik through infill development, a hierarchical and connected road network, and Transit-Oriented Development. Strengthen metro-based and polycentric development to optimize land use, reduce travel distances, and ensure balanced urban expansion.

5.2 Strategy Proposals

1. Infill development to reduce fragmented growth for a balanced growth
2. Vertical Growth
3. Road Network Hierarchy
4. Improve Link node ratio
5. Transit Oriented Development
6. Improve perimeter to area ratio
7. Metro Based Development
8. Polycentric concentrated Growth
9. Encourage Mixed used development

The strategy focuses on balanced urban growth through infill and vertical development to optimize land use. Enhancing road hierarchy and link-node ratio will improve connectivity. Emphasis on transit-oriented and metro-based development promotes sustainable mobility. Improving perimeter-to-area ratio and encouraging polycentric growth ensure compact, efficient urban forms. Mixed-use development is supported to create vibrant, walkable neighborhoods and reduce travel demand.

5.3 Spatial Proposals

1. Strategic Infill Development for Compact Development
2. Strengthening the Road Network
3. TOD Based Development on the growth corridor.
4. Polycentric Concentrated Growth Centers
5. Cluster of Amenities around metro

5.3.1 Strategic Infill Development for Compact Development

Spatial Based Proposal

a) Vertical development
b) Infill Development with using FAR and TPS.
c) Improving the Average Density
d) Improving Shape Index, porosity, reduce dispersion index

Issues- Wards 24, 25, 81, 56, 14, 13, 32, 21, 7, and 23 in Nashik present high potential for strategic densification due to the presence of underutilized land and irregular population distribution. These areas exhibit fragmented development patterns, with average densities below 8,000 people/km², contributing to spatial inefficiency and reduced land productivity. Despite their densification potential, these wards face moderate road and transit connectivity, limiting their capacity to support compact growth. The average road density of 1.83 km/sq.km reflect insufficient infrastructure to sustain higher densities or enable efficient intra-city movement.

Longer average travel distances (5.7 km excluding walk trips) in these wards stem from poor accessibility and limited public transport integration, discouraging modal shifts and increasing

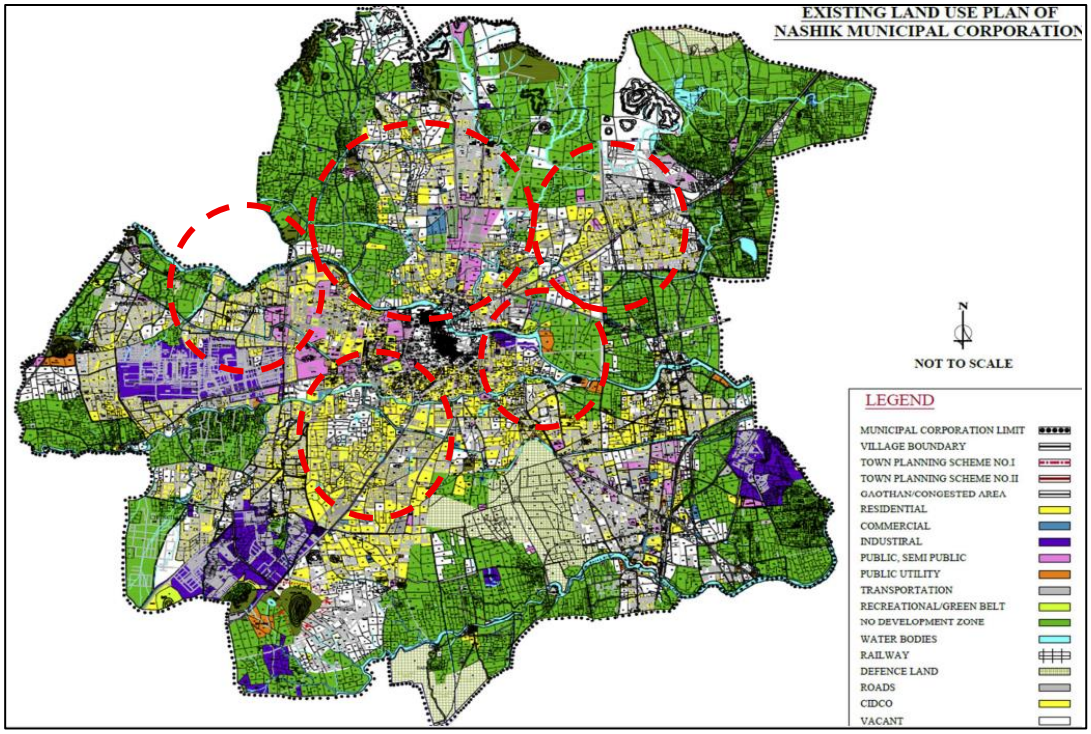


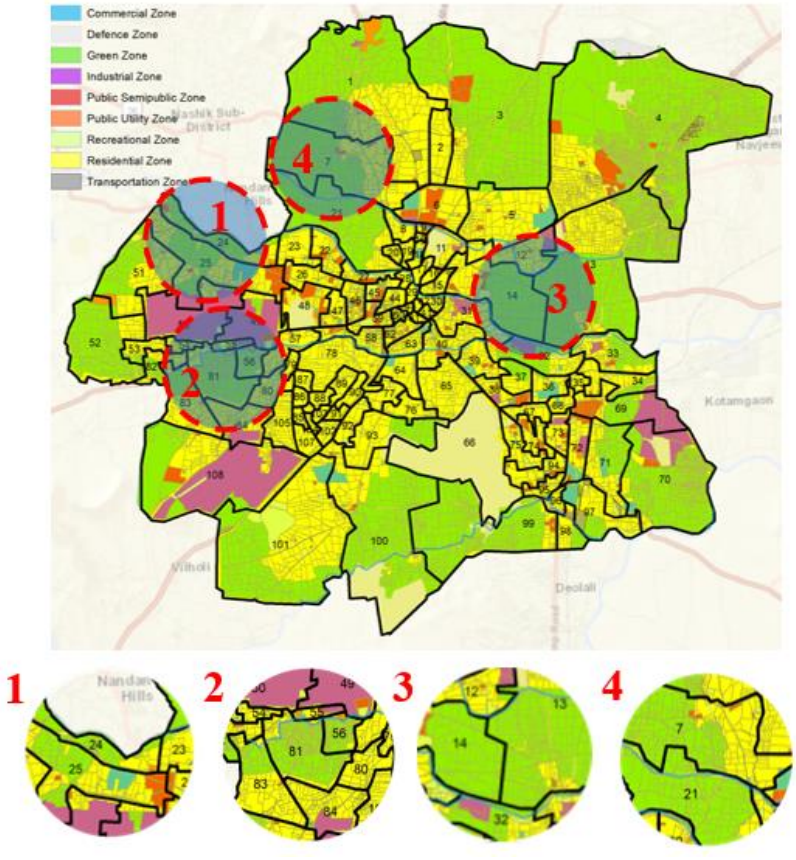
Figure 44- Land use which shows potential for Infill development (Source- CDP)

dependence on private vehicles. Furthermore, the scarcity of mixed-use and commercial functions within these zones forces residents to travel farther for employment and services, weakening economic vibrancy.

Solution -To promote a more efficient and sustainable urban structure, prioritizing infill development is essential. This approach aims to improve key spatial indicators such as the contiguity index, currently at 0.41, by fostering a more connected and cohesive urban fabric. Similarly, enhancing the porosity index—now at 52.4—will ensure a balanced network of open spaces and permeability, supporting better movement and environmental quality.

Improving the dispersion index from 1.50 toward a target of 1.20 will facilitate a more even distribution of population density across the urban area, reducing pressure on overcrowded zones and optimizing infrastructure use.

Refining the shape index (currently 0.41) will promote more compact, well-defined urban forms that reduce sprawl and inefficient land use. These location are selected based on existing infrastructure , land use and existing road network.



Existing Condition
Perimeter / Area- **0.43**
Saturation-**51.6% (0.51)**
Porosity Index -**52.4 %(0.52)**
Dispersion Index- **1.50**
Population Density – **7650/ sqkm**
Avg Travel Distance Per Person -**4.96 sqkm**

Proposed Condition
Perimeter / Area- **0.43**
Saturation-**65% (0.65)**
Porosity Index -**45%(0.45)**
Dispersion Index- **1.20**
Population Density – **13745 /sqkm**
Avg Travel Distance Per Person **-3.5 sqkm**

Figure 45- Proposed Infill Development Location

Types of infill development include residential redevelopment of vacant or underutilized lots, adaptive reuse of existing structures, subdivision of larger parcels, and incremental intensification within established neighbourhoods. These methods contribute to better land utilization and reduce outward expansion.

Densification strategies to reduce travel distances encompass vertical growth through mid-rise and high-rise buildings, horizontal infill by filling gaps between existing developments, and the introduction of mixed-use developments combining residential, commercial, and institutional uses. Transit-oriented development (TOD) and corridor densification near transit nodes further enhance accessibility and reduce dependency on private vehicles.

Strategically integrating mixed-use development, ensuring at least 30% of land within 500 meters of transit stations is mixed-use, will create vibrant, walkable neighbourhoods. This supports reduced travel distances and enhances accessibility to daily needs. A balanced urban form combining compact development with well-planned open spaces will contribute to lowering the average trip length from 4.95 km, encouraging sustainable travel behaviour and reducing congestion.

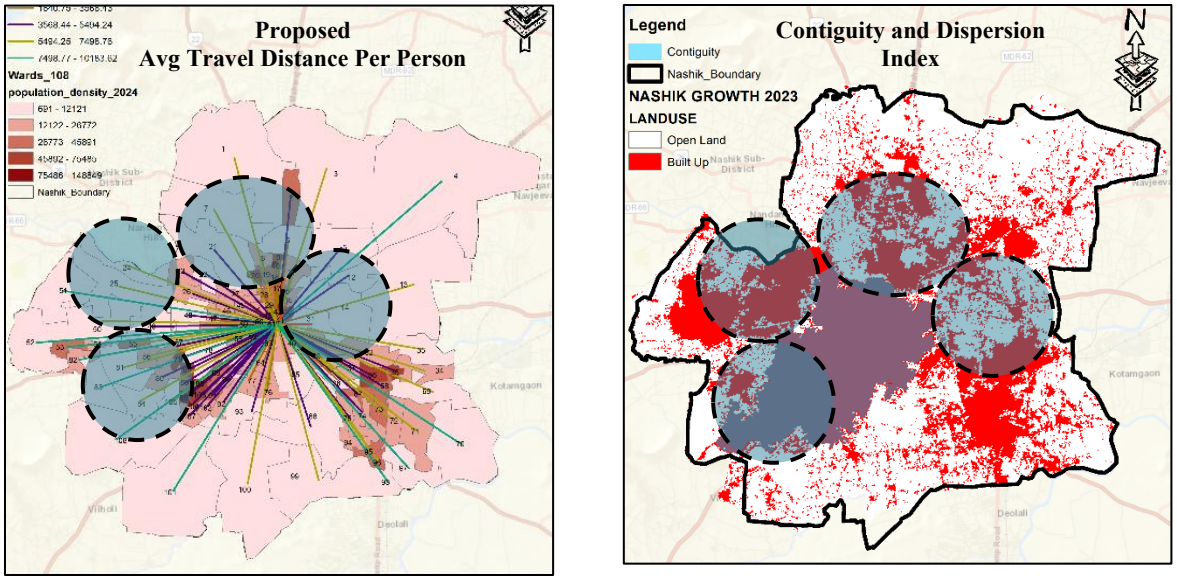
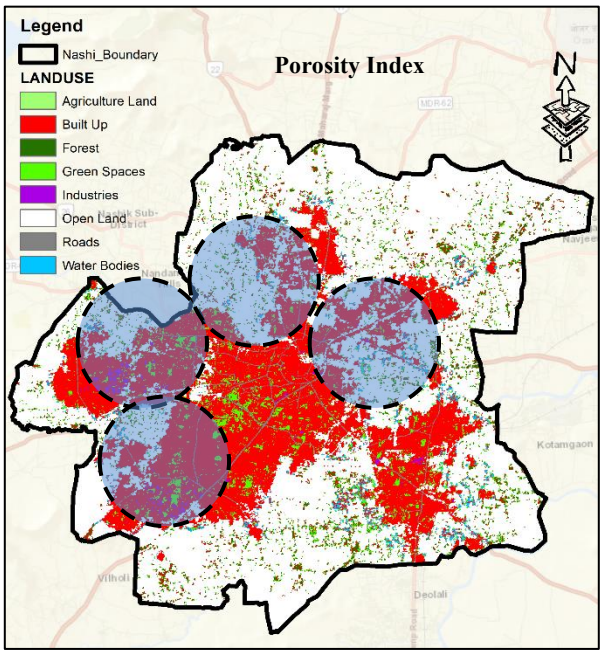
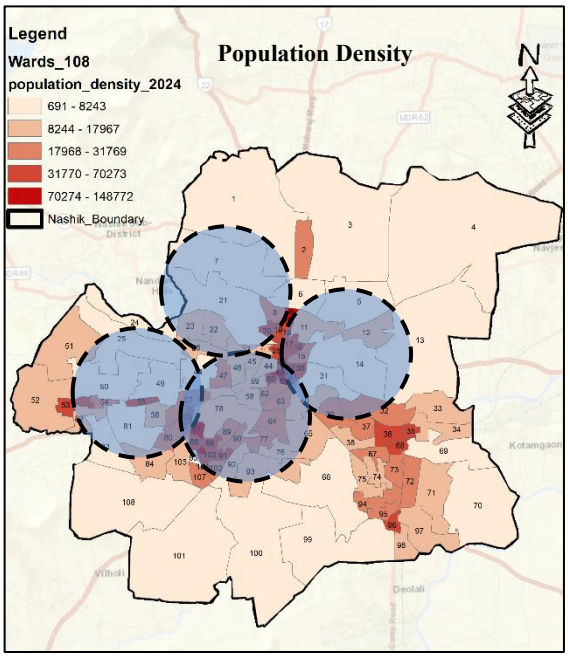


Figure 46- Improvement in the Average Travel Distance Per Person, Contiguity and Dispersion Index





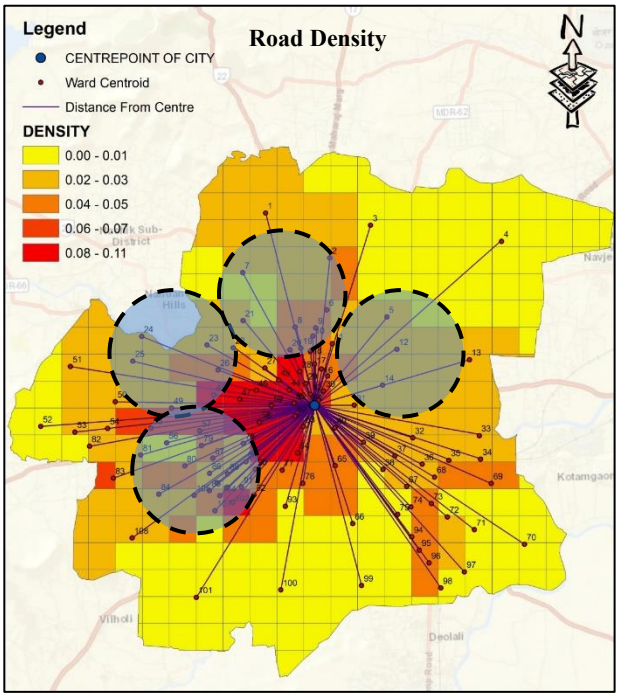


Figure 47- Saturation , Population , Road Density Proposed

With proper setbacks near natural elements, infill development is proposed to regulate the density variation of the city. This approach enables controlled densification in infrastructure-ready areas, supports sustainable land use, and aligns with broader goals of enhancing connectivity, reducing sprawl, and creating resilient urban environments.

Achieving these targets—raising the contiguity index close to 0.65, maintaining porosity above 0.45, and improving dispersion—will collectively foster a resilient and efficient urban environment aligned with sustainable development goals.

5.3.2 Strengthening the Road Network

Spatial Based Proposal

a) Outer Ring Road
b) Improving the connected road network
c) Proposal of existing road widening and new roads.
d) Improving road density

Issue-

Avg Road Density =Total Road Length/ Total Area

=491/267= 1.83

Link Node Ratio

Nodes – 930

Links- 1001

Link Node Ratio- 2400/2017 = 1.08

The current road density of 1.83 km/km² is significantly below the recommended benchmark of 5.0 km/km², indicating an underdeveloped network that limits accessibility and efficient circulation. Low road density contributes to longer travel distances, congestion on existing routes, and restricted options for traffic distribution.

The link-node ratio of 1.08, below the ideal range of 1.4 to 1.8, reflects limited connectivity due to fewer intersections relative to road segments. This weak connectivity reduces route options, compromises network resilience, and increases the likelihood of bottlenecks, adversely impacting mobility and accessibility. Addressing these challenges requires a well-defined hierarchy of roads that balances arterial, collector, and local streets to optimize traffic flow and accessibility. Additionally, the development of an outer ring road is essential to divert through-traffic away from the urban core, alleviate congestion, and support planned urban expansion.

Enhancing road density, increasing intersection frequency, and implementing a structured road hierarchy—complemented by an outer ring road—will improve network connectivity, reduce travel times, and facilitate balanced urban growth.

Hierarchy of Roads and Improving the Link node ratio

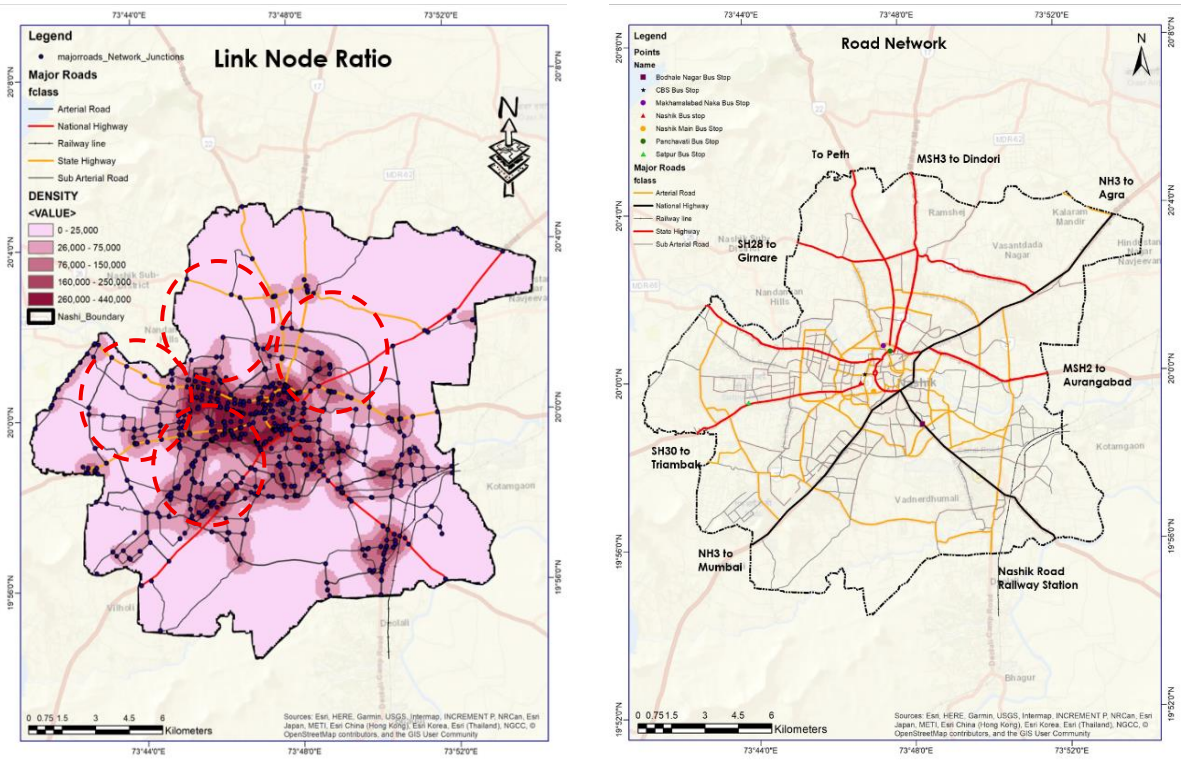


Figure 48-Indictors affecting Road Network development

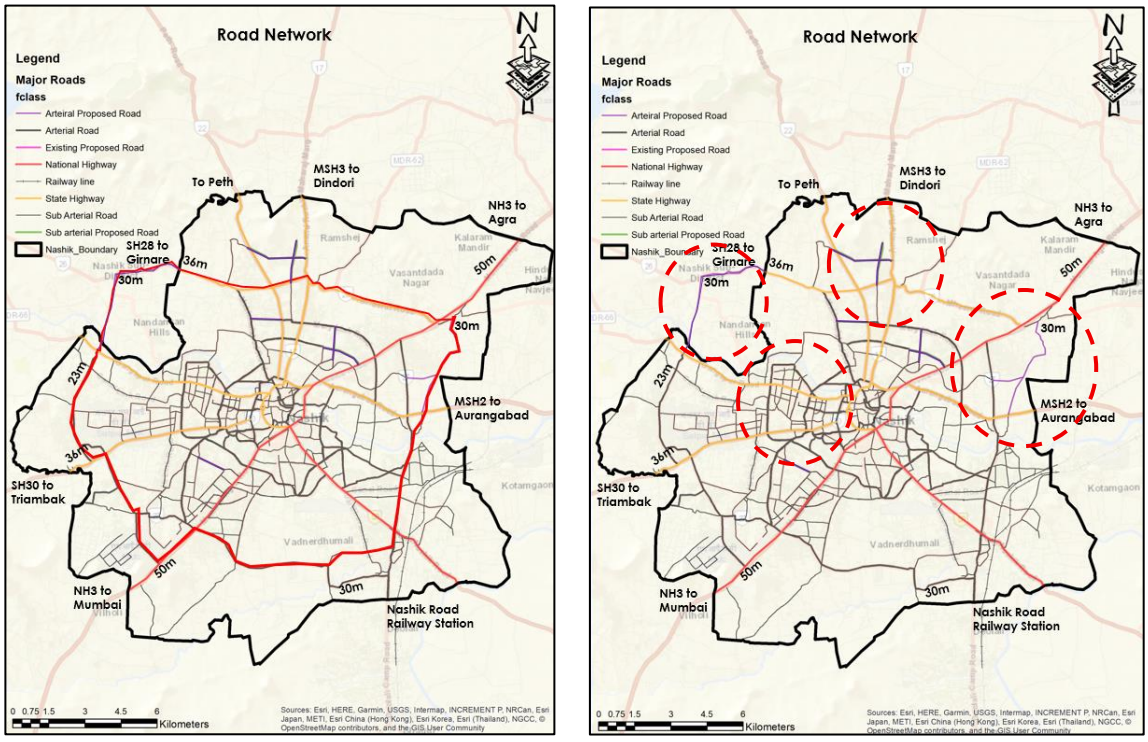


Figure 49- Proposals to Improve Road Network

Outer Ring Road

Nashik's rapid urban expansion and increasing traffic volumes have led to significant congestion in the city core and along key arterial roads. To address this, a strategically planned Outer Ring Road, with a right of way varying between 30 to 60 meters, is proposed. This corridor will effectively divert through-traffic and heavy vehicles away from the urban centre, thereby reducing congestion, travel time, and vehicular pollution.

The Outer Ring Road will enhance regional connectivity by linking major highways such as NH3 (to Agra and Mumbai), MSH2 (to Aurangabad), MSH3 (to Dindori), SH28 (to Ghoti), and SH30 (to Trimbak). It will also connect peripheral growth zones, industrial areas, and the Nashik Road Railway Station, supporting polycentric development and efficient goods movement. By relieving pressure on inner-city roads and facilitating smoother inter-city transit, the Outer Ring Road will serve as a critical infrastructure asset, promoting sustainable urban mobility and enabling the emergence of new economic corridors.With the development of the Outer Ring Road, road density is expected to increase by approximately **173%**, moving closer to the desired standard.The Outer Ring Road is projected to improve this ratio by around **30% to 67%**, enhancing overall network connectivity.Widening key arterial and sub-arterial roads allows for greater capacity, smoother movement of both private and public transport, and better access for emergency and service vehicles.

5.3.3 TOD Based Development on the growth corridor.

Spatial Based Proposal

a) TOD influenced zone
b) Land use integration
c) Local Area Plan

Nashik's urban structure is significantly influenced by two major state highways: **SH-28 (Nashik Road) and SH-30 (Trimbak Road).** These corridors play a vital role in regional connectivity, intra-city mobility, and shaping future urban growth.

SH-28 (Nashik Road) serves as a critical transit spine connecting Nashik Road railway station and adjoining industrial and residential zones with the city core. It supports high traffic volumes and facilitates the movement of goods and people, making it a key economic and commuter corridor.

SH-30 (Trimbak Road) connects Nashik to the pilgrimage town of Trimbakeshwar and serves as a major route for both local commuters and religious tourism. It also acts as a development axis for emerging residential and mixed-use zones along its length.

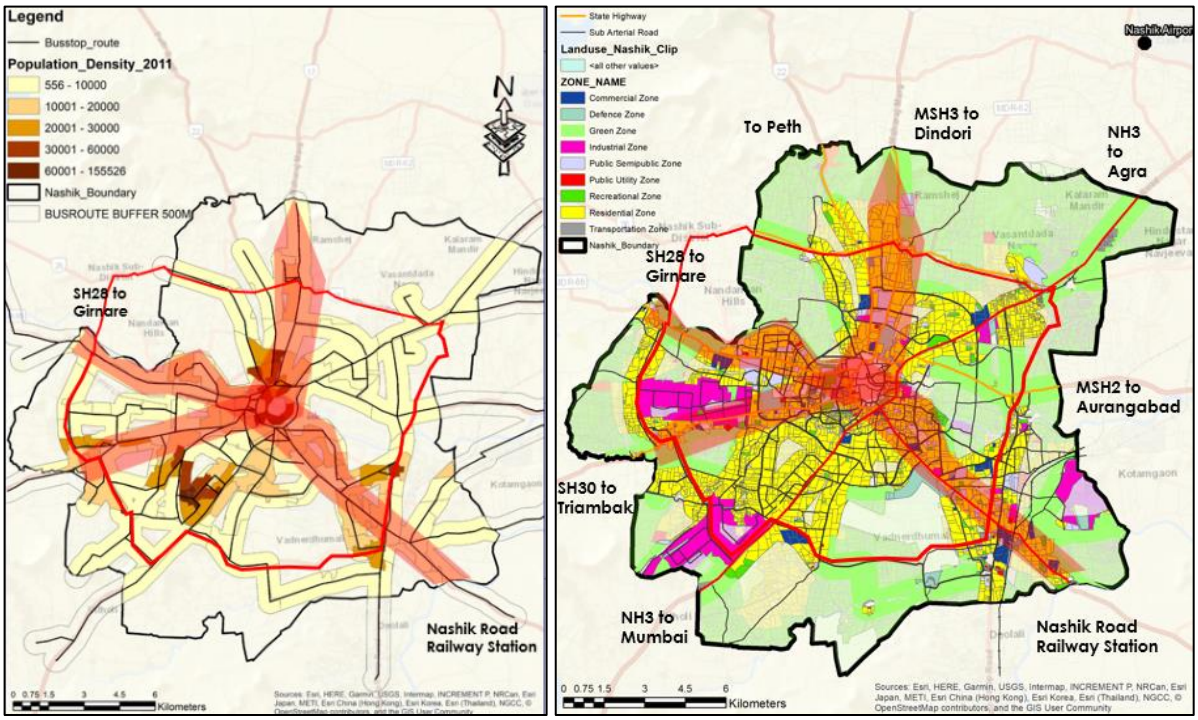


Figure 50- TOD growth corridor identification.

The identified Transit-Oriented Development (TOD) area in Nashik spans approximately 44 sq.km, accounting for around 16.48% of the city's total area. This zone is strategically located along major transit corridors, including SH-28 (Nashik Road) and SH-30 (Trimbak Road), where proposed metro and high-capacity bus systems are planned.

With a tentative 2024 population of around 12 lakhs, TOD implementation in these corridors is crucial to managing growth efficiently and sustainably. The integration of transit with urban development will enhance accessibility, reduce travel demand, and encourage high-density, mixed-use neighbourhoods around transit stations.

To support this vision, Floor Space Index (FSI) norms have been designated as follows:

- Metro Corridor: FSI of 4.0
- Bus Corridor: FSI of 2.5

Projected Peak Hour Peak Direction Trips (PHPDT) for 2036 reflect significant transit demand:

- Nashik Road Corridor: 9,364 PHPDT
- Trimbak Road Corridor: 6,465 PHPDT

Table 20- FSI Recommendation

Distance from Transit Node	**Recommended FSI**
0–200 m (Core TOD Zone)	Up to 4.0 or higher
200–500 m (Primary TOD Zone)	2.5 – 3.5
500–800 m (Secondary TOD Zone)	1.8 – 2.5
Beyond 800 m	Base FSI (1.0 – 1.5)

The Idea of Trinity Road System is a hierarchical model that divides the urban road network into three interconnected levels:

a) Arterial Roads (Mobility Corridors) These are high-capacity roads designed for fast, long-distance movement across the city and between major zones. They form the backbone of urban mobility and typically support high-speed traffic, including buses and metro corridors.

b) Sub-Arterial and Collector Roads (Distribution Corridors) These roads connect arterial routes with local streets, distributing traffic across neighborhoods. They support moderate speeds and accommodate mixed traffic, including public transport,

intermediate public transport, and private vehicles.

c) Local Streets (Access Corridors) Local roads provide direct access to residences, commercial areas, and community spaces. They are designed for low-speed traffic and prioritize pedestrians, cyclists, and local movement.

The various strategies that will help in improving the overall proposals are-

1. Mixed-Use Zoning: Ensure that at least 30% of land within 500 meters of all transit stations is zoned for mixed-use development, encouraging vibrant, walkable neighbourhoods and reducing the need for long commutes.
2. Infill Development: Promote the redevelopment of underutilized plots, particularly along sub-arterial and local corridors, to improve the contiguity index (currently 0.41), reduce urban sprawl, and enhance land-use efficiency.
3. FSI Incentives: Implement high Floor Space Index (FSI) values in transit-accessible zones—FSI 4.0 for metro corridors and FSI 2.5 for bus corridors—with targeted incentives for affordable housing and commercial development.
4. Public Transit Modal Share: These measures will enhance accessibility, increase the public transport modal share, and reduce dependence on private vehicles, thereby supporting a low-carbon, high-efficiency urban transport system.

By combining these strategies with TOD principles, Nashik can achieve a compact, connected, and inclusive urban form that aligns infrastructure development with land-use planning for long-term resilience and livability.

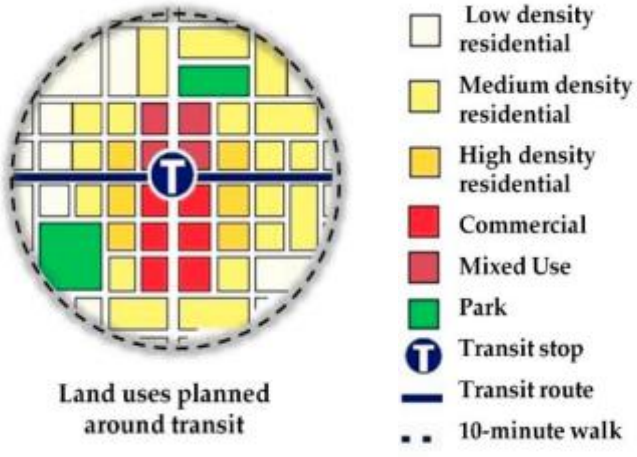


Figure 51- TOD Policy

5.3.4 Polycentric Concentrated Growth Centers

Spatial Based Proposal

a) Infill Development with Mixed use using FAR.

b) Growth Centers

c) Improve Connectivity and Accessibility

Identification of major Trip Attraction Zones

- Nashik Road – leveraging its railway connectivity and industrial activity.
- Vilholi and Pathardi – situated near major highway intersections and planned metro routes.
- Adgaon and Mhasrul – close to educational and healthcare institutions, with scope for vertical and mixed-use growth.
- Satpur-Ambad belt – as an economic hub tied to the industrial estate.

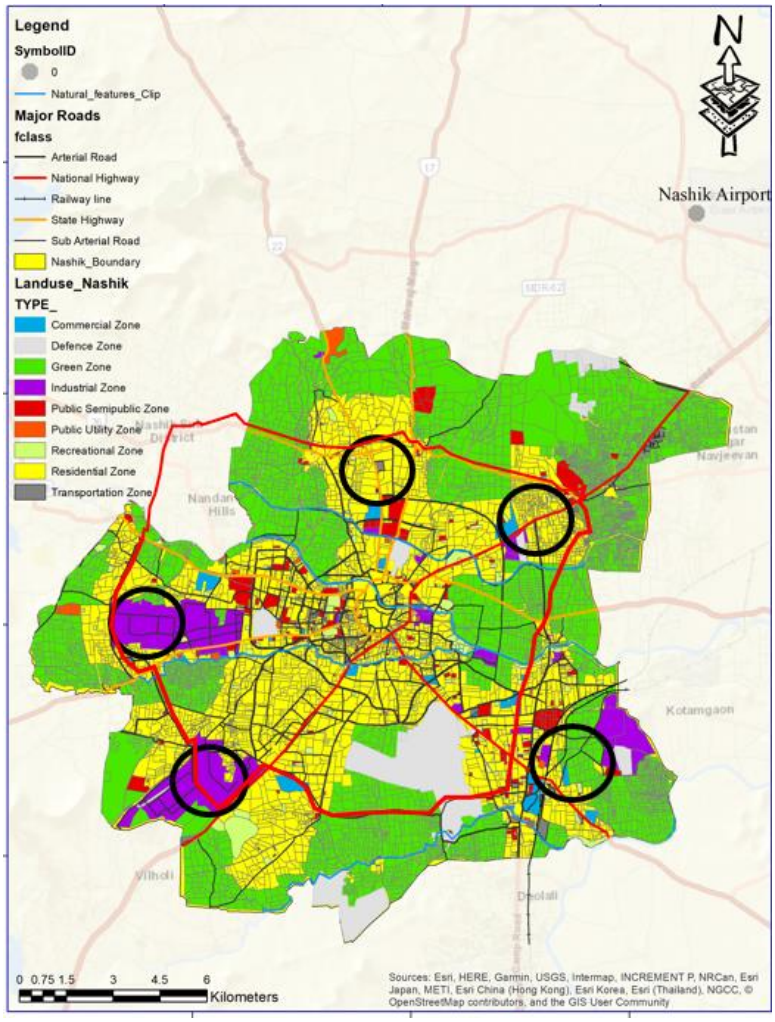


Figure 52- Identification of growth centers based in employment and tourist destination

This spatial strategy supports infill development with mixed land use based on FAR, enhances regional connectivity and accessibility, and aligns with the proposed metro route to improve last-mile connectivity. The model encourages decentralized urban growth, reduces travel distances and congestion, and enables sustainable, mixed-use urban development—positioning Nashik for resilient and inclusive metropolitan expansion.

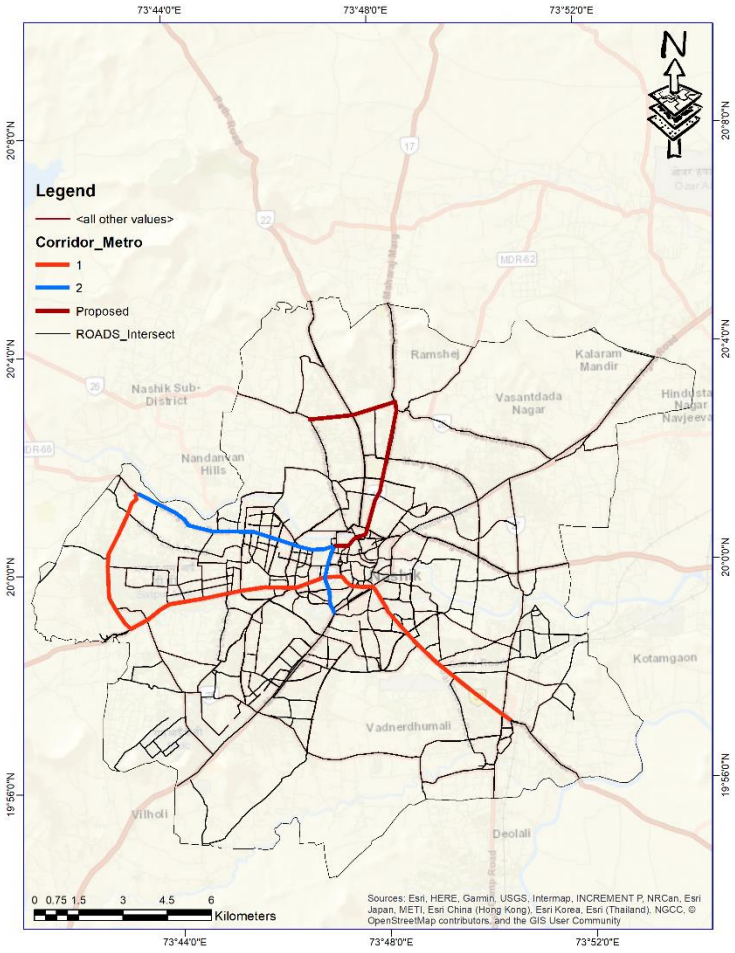


Figure 53- Proposed Metro routes

The identified growth zones are planned to drive targeted urban transformation through key strategies:

Transit-Oriented Development (TOD): Growth centers such as Vilholi and Peth Road are strategically aligned along the proposed metro corridor, enhancing accessibility and reducing dependency on private vehicles.

Decentralization of the Urban Core: By distributing infrastructure and services across six major nodes, the model reduces pressure on central Nashik, promoting more efficient land use

and service delivery.

Balanced Urban Growth: The polycentric approach enables spatial equity by fostering development in peripheral areas like Adgaon, Mhasrul, and Satpur-Ambad, supporting Nashik's projected population growth while limiting urban sprawl.

Mixed-Use Development: Zones like Nashik Road and Adgaon offer potential for vertical growth and functional diversity, integrating residential, commercial, and institutional spaces for efficient land utilization.

Reduced Travel Distance and Congestion: Strategic placement of centers near major highways and metro routes cuts average commute times and redistributes traffic loads, improving overall urban mobility and air quality.

5.4 Proposed Situation

The improvements resulting from the proposed recommendations are reflected in the enhanced scores, which contribute to a higher overall composite score for the city, indicating strengthened network performance and urban mobility.

Table 21- Improved indicators of Compactness

Indicator	Current Value	Projected Value	Score
Population Density (Gross)	77	137	3+2
Built-up Density	0.42	0.6	3+1
Saturation	51.6	65	3+1
Land-Use(% Of Road)	6%	10%	3+1
Porosity Index	52.4	45	2+2
Shape Index	0.43	0.31	3+1
Contiguity Index	0.41	0.65	2+2
Buildable Land Index	0.45	0.65	2+1
Dispersion Index	1.50	1.20	3+2

Table 22- Improved indicators of Travel Behavior

Indicator	Current Value	Projected Value	Score
Avg Trip Length Per Person	4.95 sqkm	3.5sqkm	3+1
Modal Split(Pt Share)	8%	20%	2+1
Link Node Ratio	1.18	1.8	2+1
Road Density	1.83	2.2	3+1
Transit Density	2-3 stops per sqkm	4-5 stops per sqkm	2+2
Public Transit Coverage	56.17%	65%	3+1
Proximity Index of PT (within 500m)	56%	65%	3+1

Composite Score = $\sqrt[n]{}$(Product of Scores of All Indicators)
=4 out of 5 (Good)

This improvement signifies enhanced network connectivity, better road density, and overall advancement in urban mobility and infrastructure performance.

Chapter – 6
Inferences and Challenges

6.1 Implications and Contribution

This study provides a strategic framework for understanding the impact of compact urban form on travel behavior, offering valuable insights for planners, policymakers, and urban local bodies. Its findings support evidence-based decision-making in land use planning, infrastructure development, and sustainable mobility policies. By identifying spatial and policy gaps, the study enables targeted interventions that align with national urban missions such as Smart Cities, AMRUT, and the National TOD Policy. The composite index methodology and benchmarking approach developed here can serve as a replicable model for other mid-sized cities facing similar urbanization challenges. Ultimately, the study contributes to the advancement of compact, efficient, and inclusive urban development strategies that improve livability, reduce environmental impact, and promote equitable access to opportunities.

6.2 Challenges and Limitation

There are certain challenges which might affect the project proposals and might hinder their

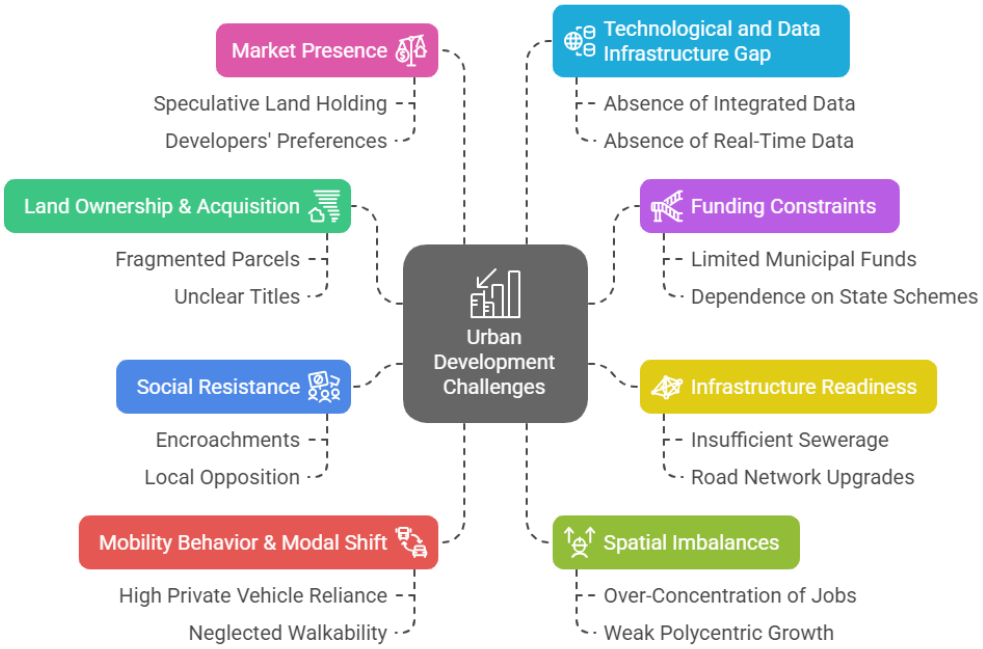


Figure 54- Challenges of the study

growth and potential.

Urban development in Nashik is constrained by a complex interplay of land, mobility, and governance challenges. Speculative landholding, fragmented land parcels, and ambiguous ownership titles significantly delay or obstruct land acquisition processes, impeding timely implementation of planned development projects. The city's high dependence on private vehicles, coupled with inadequate investment in walkable infrastructure and a general social reluctance to adopt public transport, undermines efforts to promote sustainable and inclusive mobility. Furthermore, infrastructural limitations, financial constraints, and the lack of reliable, real-time spatial and mobility data restrict the city's capacity to plan and execute compact, transit-oriented growth effectively. The uneven distribution of urban functions—particularly the over-concentration of employment in select areas—disrupts the intended polycentric urban structure, resulting in imbalanced growth patterns and increased commuting pressures. These multifaceted issues highlight the urgent need for integrated, cross-sectoral strategies that address land management, mobility, infrastructure, and institutional coordination to ensure resilient and equitable urban development in Nashik.

Chapter – 7

Conclusion and Way Forward

Compact urban form plays a vital role in promoting sustainable urban growth, a fact well-supported by existing literature, global case studies, and the contextual analysis of Nashik city. Numerous studies have consistently demonstrated that compact cities—characterized by higher densities, mixed land uses, and efficient public transport networks—contribute to reduced travel distances, improved accessibility, and enhanced environmental sustainability. By limiting urban sprawl and encouraging proximity between residential, commercial, and recreational areas, compact development fosters walkability, reduces dependence on private vehicles, and lowers per capita emissions.

This study builds upon that foundational understanding by assessing key indicators of compactness and travel behavior in the context of Nashik. The literature review enabled a comprehensive exploration of various dimensions of compactness, including density, form, accessibility, and connectivity, as well as how these influence individual travel choices. In Nashik's case, the findings reveal that a more compact urban structure can significantly reduce travel times, promote public transport usage, and make the city more accessible, particularly for low-income and transit-dependent populations.

The implications of this research extend beyond theoretical knowledge. The methodology developed—comprising benchmarking, indicator analysis, and composite indexing—offers a replicable framework that can be applied to other mid-sized cities in India facing similar urbanization challenges. It enables planners and policymakers to evaluate the effectiveness of current urban growth patterns and make informed decisions regarding land use zoning, infrastructure development, and Transit-Oriented Development (TOD).

Moving forward, the study can serve as a decision-support tool in guiding spatial planning strategies, formulating development control regulations, and prioritizing investments that align with national urban development missions. It also opens avenues for future research into dynamic urban systems, integrating real-time data, and examining long-term behavioral shifts associated with compact city policies.

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